Chemistry
TP
9
S76
V. 5

055786

CORNELL
UNIVERSITY
LIBRARY

CHEMISTRY

Cornell University Library
TP 9.S76
v.5
Spons' encyclopaedia of the industrial a
3 1924 014 800 613

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924014800613

SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES,

AND

COMMERCIAL PRODUCTS.

A.21235

CORNELL
UNIVERSITY
LIBRARY

8016 G 55

PREFACE.

In adding to existing technical literature by the issue of this Encyclopædia, the publishers believe that they are supplying a long-felt want, both in the range of subjects dealt with, and in the manner of dealing with them.

The most notable and important feature is undoubtedly represented by the Raw Commercial Products. These may be said to have a three-fold interest for Englishmen,—firstly as being mostly derived from our colonial and other possessions, secondly as forming a very large item of our carrying trade and indirect commerce, and thirdly as constituting the basis and mainstay of nearly all our great manufacturing industries. Yet singularly enough, all antecedent and contemporaneous encyclopædias have failed to treat this extensive subject in a worthy and comprehensive manner. Single articles certainly have appeared on the most prominent staples, such as cotton, indiarubber, tobacco, cinchona, olive-oil, copal; but even these have been discussed from the historical and purely scientific point of view, rather than as objects of trade and manufacture, while the thousand and one less known (though perhaps no less valuable) allied substances are totally omitted.

One of the greatest aims of this Encyclopædia is to remedy this defect, and to afford the producer, the merchant, the manufacturer, and everyone having an interest in such materials, the fullest information as to where and how they are grown and prepared, what qualifications they are required to possess, what uses they are or may be applied to, and how their adulteration and falsification may be detected.

There is manifestly great advantage in arranging these Raw Commercial Products in groups, according to their similarity of origin, character, and application, placing them in alphabetical order for facility of reference. Such is the plan followed with the important classes indicated by Drugs, Dyestuffs [organic], Fibrous Substances [from plants], Narcotics, Oils and Fatty Substances, Resinous and Gummy Substances, Spices, Starches, Sugar, Tannin, Timber, and with many smaller families. While the recognized staples of each group necessarily claim the largest space, no member, however small or apparently insignificant, has been omitted, when reliable statements concerning it could be procured; and it may be said without hesitation, that greater diligence in collecting information, and more careful accuracy in revising it, would have been difficult. For this reason alone, if for no other, this Encyclopædia must for many years remain a standard work of reference. Other subjects which do not admit of convenient grouping, such as Coffee, Cocoa, Tea, are written with similar care and minuteness. And altogether it will be found that the articles of this order, constituting the very nucleus and foundation of our great commerce and industry, are dealt with more clearly, practically, and comprehensively than has ever before been attempted in any general work, or indeed, in the majority of special treatises.

Manufactures and industries may be roughly divided into two classes, those in which chemistry plays a part, and those which are essentially mechanical. The former class embraces Acids, Alcohol, Alcoholic Liquors, Alkalies, Alum, Beverages, Bleaching Powder, Bleaching, Candles, Celluloid, Coal-tar Products, Dyeing and Calico-printing, Electro-metallurgy, Explosives, Floorcloth, Coal Gas, Glass, Indiarubber Manufactures, Leather, Manures, Matches, Mordants, Paper, Photography, Pigments and Paint, Pottery, Salt, Soap and Glycerine, Varnish, Vinegar, and many smaller articles. The mechanical industries are mainly represented by the textile arts,—Cotton Manufactures, Hair Manufactures, Hats, Jute Manufactures, Knitted Fabrics, Lace, Linen Manufactures, Rope, Silk Manufactures, Smallwares, and Woollen Manufactures.

The whole of these articles are from the pens of specialists. No pains have been spared to secure the assistance of men possessing a thorough knowledge of scientific principles, combined with the invaluable experience of actual working. Hence it will be found that the articles, instead of being mere compilations by professional writers, contain not only a critical account of the theory and practice of the modern processes, but indicate existing shortcomings, and suggest directions in which improvements should be essayed, thus having a future as well as a present value.

In the chemical articles, besides exhaustive accounts of the manufactures, illustrated by numerous diagrams, special attention is given to three subsidiary considerations which are daily assuming greater importance. The first of these is the utilization of waste. While trade is brisk and profits are large, there is too often a disposition to neglect the bye-products which are formed more or less in every works; but with dull times and keen competition has come a necessity for utilizing those accumulations of "waste," which really represent buried money. It may be said that each chemical industry forms a complement to some other; one manufacturer builds an expensive works with the object of producing the very article which another is allowing to pour from his chimney or into the drains as worthless. This evil undoubtedly arises in great measure from that neglect of high-class technical literature which marks the average British manufacturer, whence it follows that he is ignorant of the needs of every industry but his own; and it is just one of the great advantages of this Encyclopædia that it embraces all important industries, and that cross-references are given wherever two or more overlap or bear upon each other.

The second consideration, which is inseparably connected with the foregoing, is the prevention of nuisance. The legislation of the past few months has brought many more industries under penalties for creating objectionable odours and waste liquors, and the immediate future will probably witness a further extension. In this Encyclopædia, prominent attention is given to methods of ascertaining the character of escaping gases, and to means of rendering them innocuous or even useful. When manufacturers realize that every escaping vapour means money deliberately thrown away, there will be more general disposition to regard Acts for their prevention as blessings instead of evils.

The third consideration is adulteration, which may be said to have now attained to the dignity of a modern science. This subject is dealt with from both points of view, how it is done and how it may be detected.

The textile articles form a very complete review of this extensive branch of our manufacturing industry. They treat not only of the objects aimed at in the various processes, and the results produced on the fibre or fabric, but also with the construction and development of the intricate and ingenious machinery employed, the utmost impartiality being shown in describing the productions of both British and American engineering firms.

In conclusion, the publishers and editor gratefully acknowledge their indebtedness to the persons and firms enumerated in the subjoined list, adding that more than ordinary thanks are due to Wm. Lant Carpenter, B.A., B.Sc., E. M. Holmes, F.L.S., R. Marsden, F. Maxwell-Lyte, F.C.S., and A. Robottom, whose help has been invaluable in many ways.

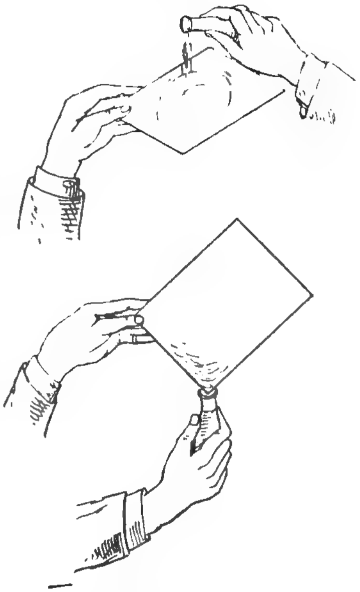
Allen, A. H., F.C.S., F.I.C., Public Analyst.
Ames, G. A., Sugar Planter, West Indies.
André, G. G., Editor to p. 640.
Arnoux, L.
Barnett, Samson, Junr.
Bevan, E. J., F.C.S., F.I.C.
Binns, R. W., Worcester.
Blackburn & Attenborough, Nottingham.
Blashfield, J. M.
Boulton & Co., Burslem.
Burt, Boulton, & Heywood.
Calderwood, J. (Price's Candle Co.).
Carpenter, W. Lant, B.A., B.Sc., &c. (C. Thomas & Bros., Bristol).
Chance Bros., Oldbury.
Chapman, J. G., M.I.C.E. (Fawcett, Preston & Co.).
Christy, T., F.L.S., Fenchurch Street.
Copeland & Co., Stoke.
Crookes, W., M.A., F.R.S.
Dobson & Barlow, Bolton.
Evans, W. N., Taunton.
Evans, Cant & Co., Stratford.
Fielding, E., Consulting Chemist.
Fisher, J., Mincing Lane and Singapore.
Fleming, W., Barrow Jute Works.
Foster, R. Le Neve, F.C.S. (Calvert & Co., Manchester).
Greville, H. L., F.C.S. (Commercial Gas Co.).
Harland, R. H., F.C.S., F.I.C., Public Analyst.
Holmes, E. M., F.L.S., Curator Museums Pharm. Soc.
Howard & Bullough, Accrington.
Hummel, J. J., F.C.S., Professor of Dyeing, Yorkshire College.
Jackson, J. R., A.L.S., Curator Museums, Kew Gardens.
Kathreiner, F., Worms.
Keighley, G., Burnley.
Leask, H., Glasgow.
Livesey, H., Blackburn.
Lomas, J. L., Alkali Manufacturer.
McNaught, J. & T., Rochdale.
Marsden, R., Editor-Associate 'Textile Manufacturer.'
Maxwell-Lyte, F., F.C.S., F.I.C.

May, Col. T. P., Louisiana.
Messel, Dr. R., Silvertown.
Milton, H., Norwich.
Minton, T., Stoke.
Morgan, W., Hat Manufacturer.
Muter, J., M.A., Ph.D., Public Analyst.
Newlands, B. E. R., F.C.S., F.I.C., Clyde Wharf Sugar Refinery.
Parr, Curtis & Co., Manchester.
Peto, A. (Plumbago Crucible Co.).
Platt Bros., Oldham.
Pope, T. A., B.Sc. (Tyne Chemical Co.).
Powell, H. J., B.A., Whitefriars Glass Works.
Procter, H. R., F.C.S., Lowlights Tanneries.
Reid, W. F., F.C.S., Stowmarket Explosives Co.
Robottom, A., Mincing Lane.
Sagar, T., Burnley.
Sibson, A., F.C.S., F.I.C.
Smith, E., Glasgow.
Spon, E., C.E., Stowmarket Explosives Co.
Stiff, E., London Pottery.
Stott, A. H., & Sons, Mill Architects.
Tatham, J., Rochdale.
Thomson, J., Photographer.
Unsworth, T., Manchester.
Walls, W., Glasgow.
Warren, T. T. P. B., F.C.S.
Webb, E., & Sons, Worcester.
Wedgwood, C., Etruria.
Westhead & Moore.
Wigner, G. W., F.C.S., F.I.C., Public Analyst.

A full and complete Index will be found at the end of the second volume.

glass bath containing 600 gr. silver nitrate, and 20 oz. distilled water. This first plate should be allowed to remain in the bath for 12 hours, after which, it should be withdrawn, when the nitrate bath will be ready for use.

1092.



Prepare another plate, and consign it to the bath, where it should remain until the greasy appearance has left the surface of the collodion film. The plate may now be placed in the dark slide of the camera, and carried to the studio, where exposure in the camera is effected.

Development.—After exposure in the camera, the plate is carried to the dark room, and there taken out of the slide. No visible change will be observed on the plate. The image is impressed, but it is latent, and may be evoked by pouring over the film a solution containing 1 oz. iron protosulphate, 1 dr. copper sulphate, 1 oz. baryta nitrate, $\frac{1}{2}$ oz. glacial acetic acid, 20 oz. water. Filter out the white precipitate, and it is ready for use.

Another formula is—$\frac{1}{4}$ oz. iron protosulphate, $\frac{1}{4}$ oz. glacial acetic acid, $\frac{1}{2}$ oz. alcohol, 8 oz. water.

Either of the above solutions may be successfully employed, but the proportions can be varied, and different reagents used in developing the latent image. After washing off all trace of the developing solution, the negative may be intensified by flowing over the plate 3 gr. pyrogallic acid, 3 gr. citric acid, 1 oz. water. To this is added, just before using, one or two drops of a mixture of 30 gr. silver nitrate and 1 oz. distilled water.

The object of intensifying is to confer the degree of opacity upon the lights necessary to yield a brilliant positive print.

If the subject be a portrait, the extreme high-lights should appear quite opaque when the plate is held up and viewed by transmitted light. When fully intensified, the plate may be washed under the tap, and fixed either by lowering into a bath containing a nearly saturated solution of sodium hyposulphite in water, or pouring over the film a solution of 100 gr. potassium cyanide to 10 oz. water.

In any case, after the negative has been cleared of the unaltered opalescent bromo-iodide of silver, it must be thoroughly washed under the tap, and reared up to dry. When dry, the negative should be slightly heated, and the following varnish (which has been filtered) applied:—1 oz. sandarac, 4 dr. seed-lac, 1 dr. castor-oil, 9 oz. alcohol. The varnish must be poured over the collodion film, and drained off at one corner of the plate, which must again be heated to drive off the alcohol, and harden the surface.

In this wet collodion process, there are distinctly marked stages of progress. The bromo-iodized collodion is in itself insensitive to light, and may be exposed to sunshine without detriment. So indeed is the silver nitrate solution. But a great transition takes place when the collodionized plate is plunged into the silver bath. The iodide and bromide in the collodion form a union with the silver salt, and produce a highly sensitive film of bromo-iodide of silver. On the successful formation of this powerful compound, hinges the entire result of the process. Should the silver bath prove too acid, the negative will be hard black and white. On the other hand, if the bath is alkaline, the negative will fog over, and lack contrast. Should white light fall upon the plate when it is sensitized, and before it is developed, the negative will fog hopelessly. If the glass plate has not been thoroughly cleaned before coating with collodion, stains will show after development. Dust flying about in the dark room and settling on the plate will cause pinholes in the negative. These may also be caused by sediments in the collodion, or in the silver bath.

Dry Collodion Processes.—The dry collodion processes are falling into disuse before their formidable rival dry gelatine emulsion. Even were they not destined to become processes of the past, they are too numerous to catalogue.

Plates prepared in the way described under the head of Collodion Process may be dried and preserved for an indefinite length of time. After leaving the silver bath, it is only needful to wash them thoroughly under the tap, and flow over them 20 gr. tannin in 1 oz. water, after which, they may be dried in a dark place, and preserved for use.

Preservatives other than tannin may be used without number, but one will serve as a type of all the others. Washing, preserving, and drying greatly reduce the sensitiveness of wet collodion plates. But this defect is to some slight extent counteracted by employing an alkaline developer:

—(*a*) 3 gr. pyrogallic acid, 1 oz. water; (*b*) 30 gr. potassium bromide, 1 oz. water; (*c*) 30 gr. ammonium carbonate, 1 oz. water.

To ½ oz. of pyrogallic solution, add 2 minims of *b*, and three of *c*. Should the image come out slowly, and be wanting in detail, add 2–3 min. of ammonia carbonate. The alkali will also add to the vigour of the negative when the image has been fully developed.

Collodion Emulsion Process.—Collodion emulsion is a mixture of iodized or bromo-iodized collodion and silver nitrate.

Washed Collodion Emulsion.—Collodion made as already described with the iodizer added should be carried to the dark room, and mixed with 1 oz. collodion, 2 min. acetic acid, 1 dr. glycerine, 4 dr. alcohol. Shake up, and set aside in the dark to settle for two days. Add 2 min. of hydrochloric acid, shake up, and again allow to digest for 24 hours. Now pour the emulsion into a shallow porcelain tray to set. When thoroughly set, cover with distilled water for one or two hours. Pour off the water, and flood with 5 gr. tannin, 2 gr. gallic acid, 2 dr. acetic acid, and 1 oz. water.

The emulsion should remain submerged for three hours. It may then be placed in flowing water until no trace of acid remains. It should afterwards be consigned to folds of clean linen, and worked about until the water has been expressed. It may now be dried at a low temperature, and preserved in a light-proof bottle.

Pellicle so made may be dissolved for use in a mixture of 1 oz. ether and 1 oz. alcohol. Plates coated with this emulsion, and dried in a warm dark room, are ready for use, and should be developed with alkaline pyrogallic acid as in the tannin process, and fixed with soda hyposulphite. Collodion-emulsion plates are more sensitive than dry collodion plates that have been washed and coated with a preservative. Intensification may be effected as with the wet process.

Gelatine Emulsion Process.—The manufacture of gelatine emulsion is one of the most recent advances in photography, and marks a new era in its history. Its introduction has rendered it possible to obtain portraits and views in the fraction of a second. Pedestrians in the streets, trains at express speed, birds on the wing, may be caught on the gelatine dry plate.

In making gelatine emulsion, the reagents required are the same as those employed in the collodion process, with this difference, that gelatine takes the place of collodion.

The manufacture of this emulsion is hedged round with difficulties, arising out of the instability and impurity of gelatine, and the rapidity with which it is decomposed by atmospheric conditions over which the chemist has no control.

It is imperative that great care be observed in selecting a suitable gelatine. Cognet's gelatine is in many respects best fitted for the purpose, but it has one great defect, small particles of grease are locked up in its flakes. These make their presence known in opaque spots in the finished plates. Nelson's "No. 1 photographic gelatine" is, on the whole, the safest to employ. Having fixed upon this gelatine, the next operation is working out the combining proportions of the haloid salts and silver nitrate, so as to leave the bromo-iodide in excess. Free silver nitrate is fatal to the process. The following is a reliable formula:—(*a*) 600 gr. gelatine, 330 gr. ammonium bromide, 10 gr. ammonium iodide, 7 oz. water; (*b*) 600 gr. silver nitrate, 7 oz. distilled water.

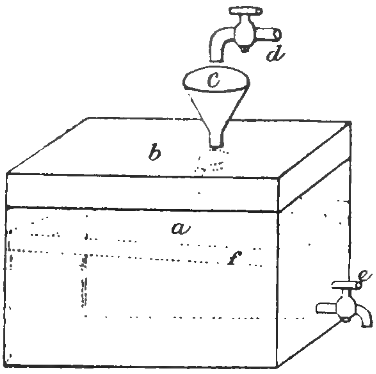
Of the above gelatine, take 500 gr. only, add to this the bromo-iodide salts and 7 oz. of water. Allow the gelatine to swell for 15 minutes, after which, place the jar containing the gelatine and salts in a hot-water bath at 71° (160° F.). Dissolve the silver nitrate in its allotted water, and raise to 82° (180° F.). Add the silver drop by drop to the gelatine solution, stirring vigorously until the last drop is taken up. Place the emulsion thus formed with its porcelain jar in a light-proof pan (an ordinary tin saucepan) half full of water, and boil for 20 minutes. Allow to cool down to about 38° (100° F.), and after swelling the remaining gelatine, add it to the boiled emulsion. Place the whole in a cool place to set. When thoroughly set, the jelly may be turned out of the jar on to a square of strong netting (preferably silk), having meshes about ⅛ in. in diameter. Spread a piece of fine white muslin over a wide basin filled with water. Gather up the netting, and force the emulsion through its folds into the water, beneath which is the sheet of muslin. This will part the jelly into thin shreds, and aid washing. The object of washing the emulsion is to get quit of the free salts in its composition, which would injure the process were they left in. It is best to employ a wooden washing-trough, Fig. 1093: *a* represents the trough; *b*, a light-proof lid; *c*, a funnel, with gas-pipe worm beneath to prevent light entering the tank; *d*, a water-tap to keep up a constant stream of water; *e*, a second outflow-tap to carry off the soluble salts which fall to the bottom of the water in the tank; *f*, a light frame, with muslin stretched across, in which the shreds of jelly rest while washing. Six or eight hours' flow of water is all that is required to fit the emulsion for use. During warm weather, ice should be placed in the water, and the feeding-funnel should be packed with ice, so as to keep the temperature below 10° (50° F.). After washing, run off the water through the lower tap, and allow the emulsion to drain for an hour or two.

The emulsion may now be scooped up with a glass spoon, and melted in a porcelain jar at 32°

(92° F.). This is best effected in a water-bath. The emulsion is now ready for coating the plates; 1 oz. of fluid should coat 1 doz. plates 4¼ × 3¼ in. All the operations described after mixing the salts with the silver must be conducted in the dark room. As a further security against light, the dark room should be illuminated by a paraffin lamp, enclosed in panels of ruby glass, covered outside with orange paper.

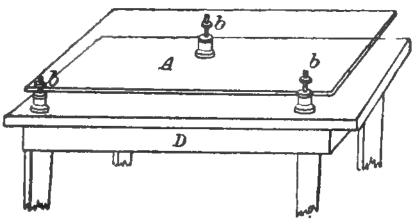
In coating the plates, it is necessary to employ a table of plate-glass (Fig. 1094) carefully levelled. The emulsion, when dissolved, should be passed through a sieve of fine muslin, to remove grit and mechanical impurities. It should then be decanted into a wide-mouthed bottle, half covered at the mouth with a membrane of muslin, which intercepts air-bells in pouring on to the plate. The addition of 2 oz. of alcohol to the pint of emulsion will cause it to flow more freely over the plate, and the plate to dry more rapidly when set. When the emulsion has been poured over the plate, spread with a glass rod, and the excess drained off, the plate may be placed upon the level table to set. When set, it should be reared up in a rack to dry. Under favourable conditions, drying will be completed in 8 hours.

1093.



Plates made by this process are so rapid as to render the use of the "drop shutter" necessary for out-door work. It must be understood, however, that what is termed "instantaneous photography" is only possible under favourable conditions of light and atmosphere. It is impossible to set down any arbitrary rules to guide photographers in timing exposure of gelatine or any other plates. So much depends on the conditions under which photographs are taken. For instance, plates prepared by the above formula may prove at one time more rapid than at another, owing to the emulsion being boiled for a longer or a shorter time, or to the salts being mixed at a higher or a lower temperature. The focal length of the objective, and the size of the diaphragm employed, as well as the light under which the photograph is obtained, are all factors to be taken into account in determining duration of exposure.

1094.



Assuming that the plate has been properly timed in the camera, it may be developed with the following alkaline pyro-solution:—(*a*) 6 gr. pyrogallic acid, 2 oz. water; (*b*) 1 oz. ammonia liq., 2 oz. distilled water, 60 gr. potassium bromide. Place the exposed plate in a shallow ebonite or porcelain tray, film uppermost, pour over solution *a*, and see that the plate is quite submerged. Drop into a glass measure four to six drops of *b*; pour back *a* into the measure, and again flood the plate by pouring back the developer. The negative will soon appear, and should be fully developed in half a minute. Wash off the developer, and fix in 5 oz. soda hyposulphite, and 10 oz. water. After fixing, wash thoroughly with water, and then consign the negative to a saturated bath of common alum, which should remain for 5 minutes. Again wash and rear up to dry. Heat must not be applied in drying, otherwise the gelatine will run. Drying may be greatly aided by pouring methylated spirit over the plate; when draining, it carries the water with it.

Intensify the negative, if necessary, with 20 gr. pyrogallic acid, 25 gr. citric acid, 6 oz. water. When required for use, to 1 oz. of this, add 4 min. nitric acid, and 20 of a mixture of 30 gr. silver nitrate, 1 oz. distilled water. This is best effected after the negative is dry, and thoroughly freed from hyposulphite, when it must be moistened in a tray of water, and the solution be poured over. The operation must be conducted in the dark room. When fully intensified, wash off, dry, and varnish, as in the wet collodion process. The gelatine plate, when dry, may be heated without risk of injury.

Retouching Negatives.—Although retouching is a sort of pseudo-art, and has nothing to do with the scientific phase of photography, it is nevertheless important, seeing that a poor negative by dint of pencilling, may be made to produce fair prints. A really good negative may also be improved by a few well-placed touches of the retoucher's pencil.

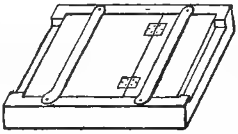
The negative to be dealt with should be set upon a table-easel, furnished with a white reflector, which throws the light up through the negative, revealing its flaws and defects. The varnish on the negative should be perfectly hard and dry. The portion to be retouched should be rubbed with the soft point of the finger, and a little finely-powdered pumice, so as to impart a tooth to the surface. The pencils used, HB and BB, should be sharply pointed. With the first, if it be a portrait-negative that is on the easel, touch out freckles or transparent spots on the face. With the BB, come lightly over the hard shadows about the mouth, nose, and eyes. But above all things, care must be taken not to overdo retouching, as it is apt to interfere with the true character of the face. Artistic perception, and a kindly appreciation of character, are valuable attributes in the professional retoucher.

Printing-processes.—Printing of positives from negatives may be divided into two classes. The first, which still finds many adherents, is based on the blackening of silver salts by the aid of light. Prints produced by this method are liable to fade. The second class includes all the modern processes, which secure permanency in the finished prints.

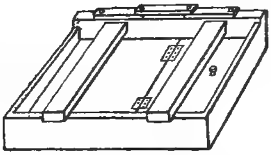
In ordinary silver-printing, the paper required is generally albuminized and salted ready for the silver-bath. This paper is best procured from a dealer. It may even be purchased sensitized, ready for the printing-frame.

To prepare the ordinary albuminized salted paper, pour into a flat dish a solution of 50 gr. silver nitrate, and 1 oz. distilled water. The sheet of paper to be sensitized is lifted, face downwards, by the two diagonal corners, and lowered on to the solution, beginning at the bend in the centre, and steadily lowering until the sheet lies flat on the surface. By this means, air-bubbles are expressed. About four minutes is sufficient to impregnate the salted surface, after which, lift a corner of the paper, and pass a glass rod beneath. Draw the paper over the rod, to get rid of superfluous moisture, and pin up to dry in the dark room. When dry, the paper is placed in contact with the negative in the printing-frame, film to film. Perfect contact is established by the pressure-frame, Figs. 1095, 1096. Now expose to light until the print is somewhat darker than required when finished. The print should be taken out and trimmed to size round the edges, the cuttings being preserved to recover the silver.

1095.



1096.



Toning the Print.—Place the print in water, to wash out the free silver; change the water several times, until no trace of milkiness is observed. Immerse the print in a bath of 1 gr. gold chloride, 4 gr. soda bicarbonate, and 8 oz. water, to be used immediately after being made up; or 1 gr. gold chloride 25 gr. soda acetate, and 8 oz. water, to be made 24 hours before being used. The red colour of the washed prints will speedily give place to a darker purpled hue, which must be a trifle darker than what is required for the finished print. Remove from the toning-bath, and wash; then immerse the print in 1 oz. soda hyposulphite, and 6 oz. water. The print should remain for 20 minutes in the fixing-solution, after which, it should be washed in running water for several hours.

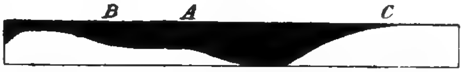
The positive, after washing, may be pressed between folds of blotting-paper, and, while damp, brushed over with a paste made of ordinary starch. Place the picture on its card mount, cover with a sheet of clean paper, and press down.

Yellow stains on the prints are caused by touching the albuminized surface with fingers soiled with soda hyposulphite. When the bath contains too little silver, it will dissolve the albumen. When the bath becomes brown, add 1 dr. powdered kaolin, shake up, and filter. The hyposulphite bath should be used only once.

Albuminized Sensitive Paper.—After salted albuminized paper has been sensitized, it may be preserved in its sensitive state, without discolouring, for several months by rendering the paper acid with citric acid. When the silver solution has been applied, and while the paper is still damp, float on a bath composed of 6 gr. citric acid and 1 oz. water. The paper should be taken from the acid bath as soon as possible, and hung up to dry. By increasing the proportion of acid, the keeping qualities are improved, but the paper should be neutralized by ammonia fumes before placing in the printing-frame.

Permanent Positive Printing.—Carbon Printing.—Theoretically, the process of carbon printing is simple; practically, it is difficult, and demands technical knowledge, and careful treatment in all its details. A principle, extremely rudimentary in itself, underlies all printing processes in which carbon or permanent pigment is used. It is that gelatine charged with potassium bichromate, when dried and exposed to white light, becomes insoluble. In addition to the bichromate in the photographic film of gelatine, it carries a powdered pigment in a fine state of division. This film, when exposed to light under a negative, is rendered insoluble, in a ratio corresponding with the lights and shadows of the negative. The deep shadows of the picture become quite insoluble while the high lights remain unchanged and perfectly soluble. Fig. 1097 represents a transverse section of the carbon film. The light passing through the clear parts of the negative has penetrated through the film at A. This point represents the deepest shadow, and most insoluble position of the film. At B, the light has pierced midway through the film, where the half tones of the negative have interposed. The film at C remains in its normal condition, no light having passed through. This point answers to the high lights of the negative. By immersing the film, so printed, in warm water, the gelatine and pigment will dissolve out at C, partly at B, and remain intact at A. In this manner, a positive print is obtained in low relief, the deepest shadow being represented at A, and highest light at C. But the pigmented film when supported on a white ground, by virtue of its semi-transparency, discloses a visible picture, having all the gradations of light and shadow of the negative from which it has been printed. The quantity of pigment held by the gelatine is so adjusted as to yield perfect opacity in the parts only where it has been most affected by the light.

1097.



Carbon-tissue, like albuminized paper, has become an article of commerce, and may be procured of almost any colour. Its preparation involves technical difficulties so grave as to render it inadvisable for photographers to attempt to make the tissue for themselves. It will be sufficient in the present instance, therefore, simply to outline the method by which it is manufactured.

The paper designed to carry the tissue must be tough, smooth, and not too heavily sized. Suitable paper is made in rolls by Rives, Stienback, and other manufacturers. The gelatine should neither be too soluble, nor too hard. It must be free from fat, chalk, acid, and alum. The gelatine should be rendered flexible by the addition of soap and sugar. Indian-ink, or other suitable colouring matter in a fine state of division, is next provided. All colours whose permanency is doubtful should be avoided. The basis must be carbon. This may be mingled with Indian red, oxide of iron, alizarine, purpurine, umber, indigo, Vandyke brown, Venetian red, bone-black, and so on. The gelatine and pigment, when mixed in proportions suitable for the sort of tissue required are consigned to a tank, and kept at a given temperature. The roll of paper to be coated is passed over the surface of the fluid at an accurately adjusted speed. The paper thus takes on a uniform coating. The speed at which this operation is carried through regulates the thickness of the coating. The roll with its film is passed into a drying-chamber, kept at a uniform temperature, and scrupulously free from noxious fumes. When dry, the tissue has the appearance of American cloth, or patent leather.

Sensitizing Carbon-Tissue.—The dry tissue cut the required size, is immersed in 1 oz. of potassium bichromate and 50 oz. distilled water. This may be done in a metallic tray, several sheets being immersed at a time, and care taken to remove air-bubbles from the surface of the tissue. The sheets should remain until they have become limp and flat, after which, they may be removed with wooden or bone forceps, as the potassium bichromate is poisonous. Each sheet, as it is brought out, should be placed face down on a plate of clean glass, and an indiarubber squeegee passed over the back, to remove superfluous moisture. This done, the tissue may be fixed to wooden clips, and hung up to dry in a dark room, free from dust.

The proportion of potassium bichromate should be varied to suit the season of the year, and the character of the negative to be printed. In warm weather, a weak bath should be used. When the negative is hard, the bath should be strengthened. A strong solution yields soft prints, whereas with a weak bath, satisfactory results are obtained from a weak negative.

In timing the exposure of a carbon print, it is necessary to use a photometer, as the tissue undergoes no visible change during the process of printing. The photometer consists of a square box, having a lid with a slit, and beneath, a ribbon of sensitized albuminized paper. The slit is formed in a coating of brown paint on a disc of glass set into the lid. When in use, the end of the ribbon is brought beneath the slit, and the box is closed. The photometer is then placed beside the printing-frame. The sensitized paper will speedily darken in the light, and assume the tone of the brown paint. Thus one tint is registered, and the ribbon is moved, so as to present a new surface in the slit.

By dint of practice, the number of tints required to print a negative is ascertained to a nicety, so that the process may be repeated successfully.

The ordinary printing-frame may be used in this process, although special frames are constructed for printing ovals and tinted margins to " card " and " cabinet " photographs.

It is essential in printing carbon-tissue to attach a narrow mask of blank or orange paper to the edges of the negative, so as to leave a margin all round the print unaffected by light.

Single Transfer.—Carbon prints by single transfer require reversed negatives; with ordinary negatives, the prints will be reversed. Reversed negatives are made in a variety of ways. By the aid of a mirror in front of the camera-objective, reversed negatives may be taken direct. They may also be obtained by the "dusting-on" process. Obernetter's formula is 1 dr. dextrine, 1¼ dr. white sugar, ½ dr. ammonium bichromate, and 3 oz. water. A glass plate is coated with this solution, drained, and dried over a spirit-lamp. It is then placed in contact with the negative, and printed in diffused light in 15–20 minutes. The plate is then laid on a sheet of white paper, and dusted over with a broad soft brush, charged with finely-powdered graphite. The print develops gradually with repeated dusting. Should the image develop at once, and indistinctly, the exposure has been too short; if on the other hand, the image is thin and full of detail, exposure has been unduly prolonged. After development, the reversed negative is coated with thin collodion, and may be placed in the printing-frame.

Another method of multiplying and reversing negatives is first to print, from the negative, a carbon positive on glass, and from this, print reversed negatives with carbon-tissue. Negatives may also be enlarged and reversed by taking a transparency from the original negative, through the camera, using either wet collodion or a gelatine dry plate. When a print is obtained on carbon-tissue from a reversed negative, it is damped in cold water, and laid face downwards on a sheet of thin transfer-paper. The paper is first laid upon a sheet of glass, the squeegee is then passed over the back of the tissue, and perfect contact is effected between tissue and paper. When squeegeeing, it is well first to cover the back of the tissue with a sheet of waterproof cloth. In about 20 minutes, the tissue and its support may be transferred to a tank of water, heated to about 35° (95° F.). The original paper on which the tissue was made will soon lift at the edges, and come away, leaving the film on the transfer-paper. All the parts unaffected by light will dissolve off, and by moving the print about, the picture will soon appear. Development must be continued until all the details of the picture are fully out, when the print may be finally washed by changing the water, and plunged into a bath of 1 oz. alum and 4 oz. water. It may then be hung up to dry. The object of placing a safe edge round the negative is to secure the perfect adhesion of the film to its support when developing. Were there no such margin, and the picture printed up to the edge of the negative, the tissue would curl up, and leave the transfer-paper. Should the print be over-exposed, warmer water should be used in development; if under-exposed, colder water.

Double Transfer Process.—Ordinary—not reversed—negatives are required for the double-transfer process. Here a waxed and collodionized glass plate takes the place of the transfer-paper employed in the method just described. A plate of glass of the finest quality should be selected, and coated with a solution of 20 gr. pure bees'-wax and 30 oz. pure benzol. The plate is levelled, and the solution is spread over the surface with a broad soft brush; then drained off, and polished with a piece of old silk, taking care not to remove too much of the wax.

Coat the plate with plain collodion, and when the film has set, plunge into a bath of cold water, and wash until the film is uniformly wet. The exposed tissue having been damped and rendered pliable, may be squeegeed down to the collodion. When this is being done, the plate should be well covered with water, and the tissue, bent up at the ends, be laid down first in the middle, and steadily lowered to the sides. After the lapse of 15 minutes, the print may be developed on its glass support.

Suitable transfer-paper is easily procured from the Autotype Co., of London, or other makers. This paper (which is enamelled) should be soaked in cold water for ½ hour, or until it becomes soft. Transfer the paper to a bath of water heated to 49° (120° F.). When the surface becomes slimy, the glass transparency and support are dipped into cold water, and the transfer-paper is laid down on its surface. It is next covered with waterproof cloth, and squeegeed into close contact. When dry, by passing a knife round the edge, the picture may be lifted from the glass, and will have a highly polished surface. In order to retain the full brilliancy of the print, it should be mounted by first trimming the edges of the picture on the glass plate, coated with warm starch or dextrine. Thin cardboard or white paper, after being damped, is laid over the back, and squeegeed down. Two or three thicknesses may be superposed, each being coated with starch. The print with its backing is then allowed to dry, after which, it may be removed from the glass support. The glaze may be retained by trimming the print after it has left the glass plate, and coating its edges only with hot starch, and, after mounting, placing it under pressure until dry.

Double transfer may be effected by using zinc plates, or ground-glass plates, by coating with wax, and omitting the collodion film.

Polished zinc imparts a glazed surface to the print, whereas ground-glass yields mat prints.

A flexible support for double transfer has been patented by J. R. Sawyer, and is supplied by the Autotype Co., of London. It is coated with gelatine rendered insoluble by means of alum.

The support requires to be waxed, and the prints dealt with in detail, in much the same way as in the methods already described.

The Woodbury Process.—The Woodbury process, like the carbon process, is based upon the action of light upon gelatine charged with potassium bichromate.

A solution of gelatine, prepared with a slight admixture of Indian-ink and potassium bichromate, is spread upon a plate of glass, and dried. When dry, the gelatine film is removed from the glass, printed, and developed, as in the carbon process. By this means, a relief is obtained. This is laid upon a perfectly flat, polished, and hard-tempered plate of steel. A plate of type-metal is then laid upon the relief, and the whole is passed between the parallel jaws of a hydraulic engine. When taken from the press, it will be found that the type-metal is impressed with a perfect reverse, or intaglio, of the relief. In other words, the leaden plate has taken the true level of the steel, the divergence from the level surface is caused by the relief, the lights of the picture being represented by the highest relief, and the shadows by the depressions in the plate.

The success of the process hinges upon the steel plate being perfectly level, and on the same conditions being observed in the construction of the press for subsequent printing. In the Woodbury photographic press, a sheet of thick plate-glass is laid upon the leaden intaglio, and the upper iron plate of the press, covered with hot cement, is let down upon the glass, which adheres to the cement.

In this manner, two parallel plains are obtained, the lower one formed by the intaglio, and the upper by the plate-glass. The next stage in printing requires that the intaglio should be slightly greased, and covered in the centre with a warm solution of semi-transparent gelatine and Indian-ink. A sheet of hard-pressed, smooth, white paper, is next laid on the ink, and the upper lid of the press is brought down, and locked. The superfluous gelatine is thus expressed, the portion left in the mould sets in 2-3 minutes, and the resulting proof is a permanent pictorial relief in Indian-ink. The high lights of the photograph have been pressed out by the projections in the intaglio, leaving the white paper exposed; while the semi-transparent jelly ascends in beautiful gradations, attaining its highest relief, and therefore its greatest opacity, in the deepest shadows. The relief is low, and when dry, the surface of the print appears to be perfectly flat. As in carbon printing, so in this process, a wide range of colour may be employed in preparing the printing-ink.

It is a purely mechanical process after the relief has been printed from the negative, and, on that account, is extremely useful in producing large numbers of prints without the aid of light. Thousands of copies may be pulled from one impression, and the number obtainable from a single gelatine relief is almost incredible.

Collotype Printing.—Collotype printing also owes its origin to the mingling of chromium salts with gelatine, but it differs from kindred processes in the principle upon which it is based. Here it is not a question of the solubility or insolubility of the gelatine film, so much as of chemical affinity. The collotype plate, after exposure in the printing-frame, is treated much in the same way as a lithographic stone. When damped over with a wet sponge, the parts unaffected by light absorb water, while the parts affected repel water, and have an affinity for fatty ink. To enter into the process more fully, two squares of plate-glass are ground together with fine emery until they are obscured. Take one of the plates, wash, and coat with 4 oz. albumen and 20 gr. ammonium bichromate. The albumen must first be beaten into a froth, and allowed to settle. Test the solution, and neutralize with dilute ammonia; coat the plate, and dry by heat at 35° (95° F.). Expose the plate to daylight long enough to print an ordinary silver positive. Wash the plate in water for ten minutes, and again dry. Coat with 1 oz. gelatine, 1 dr. potassium bichromate, and 20 oz. water. Dry by heat as before, and apply a third coating of 1 oz. gelatine (hard), 20 oz. water, 3 oz. alcohol, 100 gr. ammonium bichromate, and 15 gr. calcined magnesium. Add to this solution, just before using, 5 gr. chrome alum and ½ oz. water. Coat on a levelling-stand, and dry by heat not exceeding 38° (100° F.).

After the plate thus prepared has been printed under the negative, sponge over with water, blot off excess of moisture, and ink with a roller as in the lithographic process.

The pigment in the ink must be in a fine state of division, and rendered fluid by the addition of oil of turpentine. If the exposure of the plate has been properly timed, a positive impression in printing-ink will develop under the roller, and may be pulled off on paper in a collotype press. The plate, indeed, should yield some hundreds of proofs of uniform quality.

There are a number of methods of utilizing the properties developed by the exposure to light of bichromatized gelatine. By some methods, reliefs are obtained, and electrotyped in metal, or cast in type-metal. Copies of line engravings and drawings are thus made on a reduced or an enlarged scale, and worked with the text in ordinary printing. Some examples of this process may be seen in Tissandier's 'History and Handbook of Photography.'

Ceramic Photographs.—Encaustic photographs may be produced in a variety of ways. A secret method is practised, and excellent results obtained, by using carbon-tissue. The tissue is prepared by a special process, which obviates any risk of the gelatine cracking up during the baking of the enamel.

Another method is the "dusting-on" process, previously alluded to. But in place of employing graphite in developing the image, a finely-powdered encaustic colour is used. An exhaustive account of this process is given in the 'Photographic News Almanac' for 1881.

The substitution process is one by which the finest results are obtained. It consists in copying a negative through the camera on a wet collodion plate. But the silver of which this positive is made up, were it left in the film where burnt in, would yield a sickly-yellow picture. It is, therefore, necessary to treat the silver positive with a solution of salts of platinum or iridium, until the silver has been transformed into chloride and replaced by metallic platinum or iridium. After the chloride of silver has been removed in the fixing-butt, the picture may be transferred to its support and fired.

The collodion positive must be developed with protosulphate of iron; the image must be dense, approaching opacity in the shadows, and perfect transparency in the highest lights. When washed after fixing, it is detached from the edges of the plate by a penknife, and placed in water acidulated with sulphuric acid. This hardens the film, and it may then be floated off the glass. It is next washed free from acid in several changes of water. The film is then transferred to a solution of 2 dr. platinum chloride, and 1 oz. water. Neutralize with soda bicarbonate, then acidulate with one or two drops of nitric acid. Here the film should repose until the image is black, after which, it is fixed in 3 dr. soda hyposulphite and 1 oz. water. Again wash, and transfer the film to a basin of clean water. Place the enamelled plate beneath the film, with the collodion side next the enamel; float into position, and lay down with a fine camel-hair brush, excluding air-bubbles.

After burning in, the enamel is glazed with a flux made up of 8 parts powdered glass, 5 nitre, and 6 flint. A thin solution of indiarubber in benzol should be used as a varnish to the enamel, and the flux dusted over this, and burned in.

Platinotype Printing.—Permanent prints are obtained on paper by this process. A sheet of paper is coated with a solution of platinum chloride and iron oxalate. After the paper has been dried and exposed under a negative, a faint image is observed. This image develops into a rich black, by immersing the print in a solution of oxalate of potash, heated to 77° (170° F.). An acid water-bath is all that is required for fixing the image.

Applications of Photography.—A number of the ordinary applications of photography have already been incidentally noticed; but, in conclusion, it is necessary to catalogue other important uses to which photography has been applied. Its widest and most popular range of usefulness is found in ministering to the wants of all classes of society, and even providing the poorest families with picture galleries in miniature. But its sphere is ever widening, and its utility being demonstrated in a thousand different ways.

Apart from portrait and landscape work, the following are among the principal applications of photography:—

Reproducing works of art in permanent pigments; reproducing maps, plans, architectural and mechanical drawings, engravings, and manuscripts, by photo-engraving, photo-lithography, and collotype printing; photographs for book illustration, printed in permanent ink by Woodbury-type, collotype, and carbon process; encaustic photographs, Woodbury-type, and carbon transparencies, for art and decorative purposes; micro-photography, by means of which, microscopic objects are enlarged for book illustration, and for educational purposes in class-rooms; photo-micrography has been successfully employed in reducing official despatches, charts, newspapers, &c., to dimensions so small as to admit of their being placed in a quill, and transported by carrier pigeons to besieged cities in time of war; photographing columns of water raised by torpedoes; balloon-photography, by which photo-surveys are obtained of an enemy's country; astronomical photography, employed in photographing sun, moon, stars, and their spectra; photography in the hands of chemists has proved of the greatest service in spectrum analysis, and in investigating the phenomena of interference of the rays of the spectrum.

Photography in colour remains to be discovered, little or no progress having yet been made in this direction. It has been proved that certain colours of the solar spectrum may be reproduced on a sensitive photographic plate, and that certain other colours make no impression on the film. Having got thus far, there can be no reasonable doubt that a polychrome system of photography will be ere long discovered—a system which shall admit of the photographing of natural objects in all their varied hues. Development may be looked for in other directions as well, in the extended application of the art-science to the requirements of art education, and in its application to science. The day, indeed, may not be distant when photo-telegraphy may become an accomplished fact, when it will be possible to telegraph a portrait from one continent to another.

(See Printing and Engraving.)

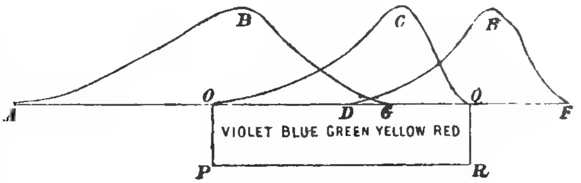
J. T.

PHOTOMETRY (Fr., *Photométrie*; Ger., *Lichtmessung*).

"Photometry" (light-measurement), or the comparison of the visible intensities of different lights among each other, is a term usually restricted to the intensity of the light in question as it affects the eye of the observer, and does not include a determination of the chemical intensity of light, which, as is well known, does not coincide with what may be called its luminosity; nor does it embrace any measurement of the intensity of the heat accompanying the light under examination.

It is a fact familiar to photographers that the most sunny days are not those on which their chemicals "work quickest," i. e. are most powerfully affected by light, some of the comparatively dull days in March, for example, being more suitable for photographic work than much brighter days later in the year. This want of coincidence between the chemical, luminous, and heating maxima in the spectrum, or coloured band produced by the decomposition of white light when passed through a prism, is illustrated in Fig. 1098, which is not, however, a representation of the spectrum of any particular light, but a typical diagram. O P R Q represents the visible part of the spectrum; the curve O C Q shows the intensity of the eye-apparent light, with a maximum over the yellow part of the spectrum; the intensity of the heat-rays is shown by curve D E F, with a maximum just outside the red end Q R; while the chemical intensity is indicated by the curve A B G, with a maximum near the violet end of the visible spectrum. The heat-measurements are usually made with a delicate thermo-electric pile, while we are indebted chiefly to Professors Bunsen and Roscoe for methods of measuring the chemical intensity of light.

1098.



In constructing photometers, or instruments for measuring the comparative brightness of two or more lights, it must be borne in mind that the human eye cannot judge directly, with any approach to accuracy, of the relative intensity of two lights, although it can determine readily whether two shadows are of equal intensity, or whether two similar surfaces of equal extent are equally brightly illuminated. The other principle involved in the use of photometers is the law that when two shadows of the same object, produced by different lights, are equally intense, or when two similar surfaces are equally illuminated, the intensities of the two lights producing this effect vary directly as the squares of their distances from the screen. Thus, if a lamp at 2 ft. and a candle at 1 ft. from the screen produced the same shadow or illuminated surface, since the square of 2 is 4, and the square of 1 is 1, the relative intensities of the two would be as 4 to 1, i. e. the lamp would be of "4-candle power."

It is necessary to fix upon some standard, in terms of which the brightness of any given light may be expressed. Various standards have been proposed at different times, such as lamps of a definite construction, burning oil of a fixed quality at a given rate per hour—for example, the French carcel lamp, or better, Parker's hot-oil lamp, but it has been found that the most uniform or least variable standard of illumination, is a wax (or spermaceti) candle, size 3 to the lb., with a wick of 27 or 28 threads of the best Turkey cotton, and burning at the rate of 125 gr. an hour. It is a candle of this kind that is referred to in speaking of gas as "16-candle," or of an electric light as of 400-candle or 6000-candle power. The standard for gas-testing, as fixed by Act of Parliament, is a sperm candle burning at the rate of 120 gr. an hour, or 2 gr. a minute. In the best photometers, as will be seen presently, the standard light is fixed upon a balance, so that its rate of burning may be constantly checked.

Before proceeding to describe the various kinds of photometers, it may be useful to consider briefly two remarkable results of careful photometric observation, which have an important practical bearing upon the most economical arrangement of a number of separate lights, whether they be candles, lamps, or gas-flames, i. e. the arrangement which will give the greatest total amount of light from the various illuminating sources.

The first is that when the flames of two lamps or candles touch each other, the luminous intensity of the combined flame is greater than the sum of the intensities of the separate flames. This effect was first observed by Dr. Benj. Franklin, and appears to be due to the increased temperature at the part where the flames overlap.

This fact has been taken advantage of by W. Sugg, in the construction of those combinations of 2, 3, or 4 flat-flame gas-burners, now so much used in the standard lamps placed at the intersections of streets, and other important points in many large English and Colonial towns. The gas-argand burner is also an extreme instance of the kind, the ring there being made up of a series of round-hole jets, each single flame of which overlaps the flame on either side of it.

The second result may be thus expressed:—A comparison of the amounts of light afforded by the same number of flames in different relative positions proves that flame is perfectly transparent, and thus that the luminous effect of a row of lights is the same whether this arrangement is parallel with or perpendicular to the direction of the rays; similarly a flat gas-flame gives the same degree of light in all directions.

The chief forms of photometer will now be described. The simplest, most readily constructed, and most easily used, is that known as Rumford's. It consists merely of a black cylindrical rod mounted vertically upon a stand or foot, and of a white screen upon which to receive the shadows of the rod. The lights to be compared (all others should be put out) are placed about until the respective shadows cast by the rod are of equal depth. The distances of the lights from the screen are then carefully measured, and each number thus obtained is multiplied by itself. The proportion between these products represents the relative intensities of the lights under examination. For example, suppose lamp A at 21 in. and lamp B at 30 in. from the screen gave equally deep shadows, then, since 21 × 21 = 441, and 30 × 30 = 900, lamp A is to lamp B as 441 to 900, or nearly as 1 to 2, or, in other words, lamp B gives twice as much light as lamp A. As a similar calculation has to be made in all photometric tests (though it is frequently assisted by previously constructed tables suited to each instrument), it will not be repeated.

Bunsen's photometer depends on the equal illumination of two surfaces, and is much more exact than the preceding. The principle of it, with very slight modifications, is adopted in the delicate photometers used in gas-testing. The essential part of it is a piece of thin paper stretched in a frame, and the paper is rendered semi-transparent by being saturated with a solution of spermaceti in turpentine-oil, with the exception of a central spot about 0·75 in. in diameter, which is allowed to remain opaque. In using it (in a dark room), the standard light is placed behind the spot, and the variable one in front. When the two surfaces are equally illuminated, the opaque spot disappears, and the whole surface of the disc is perfectly homogeneous in appearance.

Wheatstone's photometer consists of a small silvered polished bead, mounted upon a stem to which a looped motion is given by appropriate clockwork. When it is placed between two sources of light, and the clockwork is set in motion, two looped curves of different brightness are seen, so very close together that their intensities can readily be compared; the lights are then adjusted to give curves of equal brightness, and their respective distances are read off. The formation of a luminous curve by a moving bright bead, depends, of course, upon the well-known principle of "persistence of vision," the simplest illustration of which is the circle of fire traced by a lighted stick whirled round by hand.

Letheby's and Evans's photometers are similar in construction, and both depend upon the principle of Bunsen's. Letheby's consists essentially of a long bar, at each end of which are supports for a light, one being the standard candle upon a Keates's candle-balance. Upon the rod, slides a box, with holes on each side and in front; it contains the semi-transparent paper with the opaque spot. The box is moved until the spot disappears, when a pointer attached to the box indicates on a scale the intensity of the unknown light in terms of the standard. Evans's is a similar instrument, but the box is fixed, and the lights move along the bar.

In gas-testing, one or other of these instruments is usually employed, with a great number of adjuncts, such as gas-meters, pressure-gauges, &c., &c. The gas is burnt at the rate of 5 cub. ft. an hour in a No. 1 Sugg's London Argand for 14- to 16-candle gas, and in a Sugg's No. 7 steatite bat's-wing, for cannel gas. Many precautions have to be taken to correct the meter as to the rate of burning. Observations are taken every minute for ten minutes, and an average of the whole is taken as the result. A "jet photometer" is used as a rough and ready test in gas-works; it depends on the fact that, to maintain a flame or jet at a constant height (from a given circular orifice), the poorer the gas in quality, the greater is the pressure of gas required. This pressure can be delicately measured, and, with the aid of tables, can be translated into illuminating power in candles. Sugg's new "patent illuminating-power meter" depends upon an extension of this principle.

The Dispersion Photometer.—When very intense lights, such as the oxy-hydrogen, the magnesium, or the electric, have to be compared with gas or candles, it would be very inconvenient to remove the stronger light to the necessary distance (50 ft. or more) from the screen. This difficulty has been ingeniously overcome by passing the intense light through a concave lens, thus dispersing it, and lessening its intensity. The curvature and focal length of the lens being known, the amount of dispersion is easily calculated, and this dispersed light, with its intensity thus diminished to a known extent, is employed in the photometer. In the case of the electric light, it is usual to make two observations, one through green, the other through red glass.

Jansen has just constructed a photographic photometer, consisting of a frame with a sensitized plate, before which, and in the path of the light-rays to be measured, a screen with triangular perforations is made to pass. A gradation of shade, decreasing from the base of the triangles towards the apex, is thus obtained, and points of equal shade indicate equal intensity. It is stated that he has in this way been able to express the illuminating power of some of the stars in terms of that of the sun, and it is expected that he will be able to construct a definite solar scale, to which all artificial lights may be referred.

The recent wonderful researches of Alex. Graham Bell, assisted by Tainter, upon sounds produced when beams of light, interrupted rapidly by perforated discs revolving at high speed, fall upon various substances, seem to point to the possibility of constructing an instrument in which the different intensities of two lights will make themselves evident in differences of audible tones, when the rays from each of them fall upon suitably constructed receivers containing lamp-black, and provided with hearing tubes to convey to the ear the sounds produced by the successive impact of interrupted light-rays.

Illuminating Value.—In order to arrive at a true estimate of the actual money-value of any illuminating material, it is necessary to take into account not merely its light-intensity, as determined by the photometer, but also the rate at which it burns, and its price (per lb.). There are therefore three variable elements, each one of which must be duly considered. If, for example, paraffin and stearine (or composite) candles give equal light photometrically, and 1 lb. of stearine candles lasts 48 hours, while 1 lb. of paraffin lasts 54 hours (146 gr. and 129 gr. per hour respectively), it is obvious that if the stearine candles cost 8*d*. a lb., and the paraffin cost 8¾*d*., the paraffin is really the cheaper of the two, and at 9*d*. would cost the same.

Some writers throw this calculation into the form of "cost per 100 of light," where the 100, or standard, is taken from a standard "hot-oil" lamp, burning every hour 815 gr. of oil, or 0·1164 lb. at 11*d*. a lb. Hence in this case, the cost per 100 of light is 0·1164 × 11 = 1·2804*d*. Comparing this with a wax candle, burning 125 gr. an hour, giving only $\frac{1}{11}$ the light of the lamp, and costing 2*s*. 6*d*. or 30*d*. a lb., we have as the cost per 100 of light,—

$$125 \times 11 = 1375 \text{ gr., or } 0{\cdot}1964 \text{ lb.} \times 30 = 5{\cdot}892d.$$

Proceeding in this manner, Dr. Frankland has drawn up the following tables of illuminating equivalents, or the quantities of different illuminating materials necessary to produce the same amount of light:—

Young's paraffin-oil	1·00 gal.	Sperm candles	22·90 lb.
American petroleum, No. 1 ..	1·26 „	Wax „	26·40 „
„ „ No. 2 ..	1·30 „	Composite „	29·50 „
Paraffin candles	18·60 lb.	Tallow „	36·00 „

Taking into account the market prices of these various materials, he concludes the comparative cost of the light, equal to that of 20 sperm candles (each burning for 10 hours at 120 gr. an hour), to be:—

	s.	*d.*		*s.*	*d.*
Wax	7	2½	American petroleum	0	6½
Spermaceti	6	8	Young's paraffin-oil	0	5
Paraffin	3	10	Coal-gas	0	4½
Tallow	2	8	Cannel-gas	0	3
Sperm-oil	1	10			

It may be remarked, in passing, that the difference in favour of gas, as against candles, is very much reduced in practice, since users of gas always habituate themselves to a much more intense light than when they employ candles. Probably the same thing will obtain, *mutatis mutandis*, when domestic electric lamps are substituted for gas.

Taking into account the cost of material, its rate of consumption, its market price per lb., and its light-power, Peclet gives the following valuable table, upon the data that:—1 pint of oil costs 5*d*.; 1 lb. tallow candles, 7*d*.; 1 lb. wax candles, 2*s*. 2*d*.; 1 lb. stearine candles, 1*s*. 4*d*.; 100 ft. coal-gas, 7*d*.; 100 ft. oil-gas, 2*s*. 3*d*.; and that 1000 ft. coal-gas = 44½ lb. sperm, or 51 lb. stearic acid, or 6½ gal. colza-oil, or 5·9 gal. sperm-oil.

Means of Illumination.	Intensity of the Light.	Consumption of Illuminating Material per Hour.	Illuminating Power: Carcel's Lamp = 100.	Price of 100 grm. of Illuminating Matter.	Cost of the Light per Hour.	Cost of a Light of the same Intensity per Hour.
				d.	*d.*	*d.*
Tallow candles, 6 to the lb. ..	10·66	8·5	54·04	1·5	0·125	1·169
Wax „ 6 „ ..	14·60	9·6	61·57	5·0	0·461	3·155
Stearine „ 5 „ ..	14·40	9·3	66·58	3·2	0·298	2·066
Kitchen lamp	6·65	8·0	33·60	1·4	0·083	1·246
Flat-wick lamp	12·50	11·0	47·50		0·114	0·912
Astral lamp	31·00	26·7	48·70		0·280	0·893
Sinumbra lamp	56·00	37·1	63·00		0·385	0·687
Inverted reservoir lamp	90·00	43·0	87·8		0·446	0·495
Hydrostatic lamp	45·00	17·26	109·2		0·179	0·398
Carcel's lamp	100·00	42·00	100·0		0·435	0·435
Vapour „	130·70	151·00	36·2	1·3	2·013	1·207
		cub. ft.		Per 1000 cub. ft.		
Coal-gas	127·00	8·70		7·0	0·580	0·456
Oil-gas	127·00	2·43		19·2	0·630	0·367

(See Candles; Gas [Coal]; Oils—Illuminating Values.)

W. L. C.

PIGMENTS AND PAINT.

Pigments (Fr., *Pigments*; Ger., *Farben*).—The term "pigments" is applied to those colouring matters which are mixed in a powdery form with oil or other vehicle for the purpose of painting. They differ in this respect from the dyestuffs (see Coal-tar Products, pp. 641–684, and Dyestuffs, pp. 854–869). Their preparation for use and their application are described hereafter in the section on Paint (see pp. 1552–1556); the present article embraces only their origin and production. A very large proportion of the pigments are derived from the mineral kingdom. Organic colouring matters for use as pigments are mostly made in the form of "lakes," by one of the three following methods :—(*a*) To a filtered solution of the colouring matter, is added a solution of alum; the whole is agitated, and the colour is precipitated by a solution of carbonate of potash. (*b*) A solution of the colouring matter is made in a weak alkaline lye, and precipitated by adding a solution of alum. (*c*) Recently-precipitated alumina is agitated with a solution of the colouring matter as before, until the liquid is nearly decolorized, or the alumina assumes a sufficiently deep tint. The first method is generally adopted for acidulous solutions of colouring matter, or those injured by alkalies; the second, for those not injured by alkalies; the third, for those whose affinity for gelatinous alumina enables them to combine with it by mere agitation. (See Alumina, p. 333.)

It will be convenient to describe pigments under the heads of the chief colours, in alphabetic order—blacks, blues, greens, reds, whites, and yellows.

Blacks.—See article Blacks, pp. 452–456.

Blues. *Cobalt Blue.*—A mixture of 8–10 parts alumina, freshly precipitated and freed from water, and 1 part arseniate or phosphate of cobalt, slowly dried, and heated to dull redness.

Paris Blue.—(*a*) A thorough mixture of 2 parts sulphur and 1 part dry carbonate of soda is gradually heated in a covered crucible to redness or till fused; a mixture of silicate of soda and aluminate of soda is then sprinkled in, and the heat is continued for an hour; the little free sulphur present may be washed out by water. (*b*) An intimate mixture of 37 parts China-clay, 15 parts sulphate of soda, 22 parts carbonate of soda, 18 parts sulphur, and 8 parts charcoal, is heated in large crucibles for 24–30 hours; the mass is re-heated in cast-iron boxes at a moderate temperature till the desired tint appears, and is finally pulverized, washed, and dried. (*c*) Gently fuse 1075 oz. crystallized carbonate of soda in its water of crystallization; shake in 5 oz. finely-pulverized orpiment, and, when partly decomposed, as much gelatinous alumina hydrate as contains 7 oz. anhydrous alumina; add 100 oz. finely-sifted clay, and 221 oz. flowers of sulphur; place the whole in a covered crucible, and heat gently till the water is driven off, then to redness, so that the ingredients sinter together without fusing; the mass is then cooled, finely pulverized, suspended in river-water, and filtered. The product is heated in a covered dish to dull redness for 1–2 hours, with occasional stirring. Colourless or brownish patches may occur, and must be removed.

Prussian Blue.—(*a*) A solution of 2 parts alum and 1 part sulphate of iron is made in water; a solution of yellow prussiate of potash is then acidulated with sulphuric acid, and some of the first solution is dropped in till the precipitate falls slowly; the latter is well washed on a filter, and dried. (*b*) Mix a solution of protosulphate of iron with one of red prussiate of potash; wash and dry.

Saxon Blue.—Dissolve 1 oz. sulphate of iron and 8 oz. alum in 1 gal. water; add separate solutions of prussiate of potash and pearlash, until the precipitation ceases; collect the precipitate after some time; wash thoroughly, and dry.

Ultramarine.—The preparation of ultramarine from the gem lapis lazuli (see Gems, p. 1042) no longer survives. Artificial ultramarine, of which, some 10,000 tons are made annually, is composed approximately of 46·60 per cent. silica, 23·30 alumina, 3·83 sulphuric acid, 21·48 soda, 1·06 peroxide of iron, and traces of lime, sulphur, and magnesia. The ingredients employed are sometimes China-clay, sulphate of soda, charcoal or pit-coal, and rosin; or China-clay, soda, silica, sulphur, and rosin. Their proportions are a matter of secrecy, but may be deduced pretty accurately from the percentage composition just given. The raw materials are ground very fine, well mixed, pressed into muffle-furnaces, and calcined at a red heat for 12–36 hours, or until the sulphur is nearly burnt off. When the firing is complete, the furnaces are closed tightly, and the material is allowed to cool, requiring 5–6 days. The product is green ultramarine, which is then roasted with finely-powdered sulphur in pans under the influence of the air. After washing, it is ground in wet mills for 2–5 days, settled under the action of heat, repeatedly washed, classified, dried, bolted, and packed.

Greens. *Baryta Green.*—Mix 2 parts caustic soda and 1 part chlorate of potash, and gradually add 2 parts very finely powdered manganese; heat gradually up to dull redness, then allow to cool, powder, and exhaust with water; filter and cool, and add a solution of nitrate of baryta to the filtrate. A violet-coloured baryta precipitate forms; this is carefully washed, dried, and treated with ½–1 part of caustic baryta, hydrated, and gradually heated up to redness, with constant stirring. The cooled mass is powdered, and finally washed to remove any excess of baryta.

Brighton Green.—Separately dissolve 7 lb. sulphate of copper and 3 lb. sugar of lead, each in 5 pints water; mix the solutions, stir in 24 lb. whiting, and when the mass is dry, grind to powder.

Brunswick Green.—(*a*) Pour 3 parts saturated solution of sal ammoniac over 2 parts copper-filings, contained in a vessel capable of being closed, and keep the mixture in a warm place for some weeks, when the newly-formed pigment is separated from the inoxidized copper by washing on a sieve; it is then washed with water, and slowly dried in the shade. (*b*) A solution of crude carbonate of ammonia is added to a mixed solution of alum and blue vitriol, as long as it affects it; in a short time, the precipitate is collected, washed, and dried. (*c*) Lighter shades are produced by the addition of sulphate of baryta, or alum.

Chrome or Guignet's Green.—Fuse together 3 parts boracic acid and 1 part bichromate of potash at a dull-red heat on the hearth of a flame-furnace. This forms a borate of chromium and potash, with evolution of oxygen. The mass is repeatedly washed with boiling water, which causes decomposition, and consequent separation of hydrated oxide of chromium and a soluble borate of potash. The oxide is washed, and ground very fine.

Emerald Green.—Form a paste with 1 part verdigris in sufficient boiling water, pass it through a sieve to remove lumps, and gradually add it to a boiling solution of 1 part arsenious acid in 10 parts water, the mixture being constantly stirred until the precipitate becomes a heavy granular powder, when it is filtered through calico, and dried.

Manganese Green.—Intimately mix 3–4 parts caustic baryta moistened with water, 2 parts nitrate of baryta, and 2 parts oxide of manganese; place in a crucible heated to dull redness, fuse, pour out, pulverize, digest in boiling water, wash in cold water, and dry in an atmosphere free from carbonic acid.

Mountain Green.—(*a*) Native green carbonate or bicarbonate of copper is ground to powder, either with or without addition of a little orpiment or chrome yellow. (*b*) Add a solution of carbonate of soda or potash to a hot mixed solution of alum and sulphate of copper.

Prussian Green.—A mixture of Prussian blue and gamboge.

Sap Green.—(*a*) The juice of buckthorn berries (see Drugs, p. 795) is extracted by allowing them to ferment in wooden tubs for 7–8 days, and pressing and straining; a little alum is added to the juice, which is evaporated down to a suitable consistence, and run into bladders to dry and harden. (*b*) Mix 11 oz. powdered arsenious acid, 1½ lb. carbonate of potash, and 1 gal. boiling water; dissolve, filter, and add to another solution of 2 lb. crystallized sulphate of copper in 3 gal. water, producing 1½ lb. of pigment.

Scheele's Green.—Dissolve 1 part powdered white arsenic and 2 parts commercial potash in 35 parts boiling water; filter, and add the solution gradually, while still warm, to a filtered solution of 2 parts sulphate of copper, as long as a precipitate falls; wash with warm water, and dry.

Vienna or Schweinfurth Green.—(*a*) Dissolve 8 lb. arsenious acid in the least possible quantity of boiling water, and add it to 9-10 lb. verdigris in water at 48½° (120° F.) passed through a sieve; set aside the mixed ingredients till the mutual reaction produces the desired shade. (*b*) Dissolve 50 lb. sulphate of copper and 10 lb. lime in 20 gal. good vinegar, and add a boiling-hot solution of 50 lb. white arsenic as quickly as possible; stir several times, allow to subside, collect on filter, dry, and powder. The supernatant liquid is employed to dissolve the arsenic for the next lot.

Douglas' Green.—Barium chromate is precipitated by adding to a solution of barium chloride a sufficiency of a soluble chromate to effect complete separation; to the lemon-yellow chromate, is added 20 per cent. of strong sulphuric acid, which produces a deep-red by the liberation of chromic acid; the mass is then ground, and heated to redness, when it becomes green.

REDS. *Brazil-wood Lake.*—(*a*) Digest 1 lb. ground Brazil-wood in 4 gal. water for 24 hours, boil ½ hour, and add 1½ lb. alum dissolved in a little water; mix, decant, strain, add ½ lb. tin solution, again mix well, and filter; to the clear liquid, cautiously add a solution of carbonate of soda while a precipitate forms, avoiding excess; collect, wash, and dry. The shade will vary according as the precipitate is collected. (*b*) Add washed and recently precipitated alumina to a strong filtered decoction of Brazil-wood.

Carminated Lake.—(*a*) The cochineal residue left in making carmine is boiled with repeated portions of water till exhausted; the liquor is mixed with that decanted off the carmine, and at once filtered; some recently precipitated alumina is added, and the whole is gently heated, and well agitated for a short time; as soon as the alumina has absorbed enough colour, the mixture is allowed to settle, the clear portion is decanted, and the lake is collected on a filter, washed, and dried. The decanted liquor, if still coloured, is treated with fresh alumina till exhausted, and thus a lake of second quality is obtained. (*b*) To the coloured liquor obtained from the carmine and cochineal as just stated, a solution of alum is added, the filtered liquor is precipitated with a solution of carbonate of potash, and the lake is collected and treated as before. The colour is brightened by addition of tin solution.

Carmine.—Boil 1 lb. cochineal and 4 dr. carbonate of potash in 7½ gal. water for ¼ hour. Remove from the fire, and stir in 8 dr. powdered alum, and allow to settle for 20–30 minutes. Pour the liquid into another vessel, and mix in a strained solution of 4 dr. isinglass in 1 pint water; when a skin has formed upon the surface, remove from the fire, stir rapidly, and allow to settle for ½ hour, when the deposited carmine is carefully collected, drained, and dried.

Cochineal Lake.—(*a*) Digest 1 oz. coarsely powdered cochineal in 2½ oz. each water and rectified alcohol for a week; filter, and precipitate by adding a few drops of tin solution every 2 hours, till the whole of the colouring matter is thrown down; wash the precipitate in distilled water, and dry. (*b*) Digest powdered cochineal in ammonia water for a week; dilute with a little water, and add the liquid to a solution of alum as long as any precipitate (lake) falls. (*c*) Boil 1 lb. coarsely powdered cochineal in 2 gal. water for 1 hour; decant, strain, add solution of 1 lb. cream of tartar, and precipitate with solution of alum. By adding the alum first and precipitating the lake with the tartar, the colour is slightly changed.

Indian Red.—(*a*) Sulphate of iron is calcined until the water of crystallization is expelled, then roasted by a fierce fire until acid vapours cease to arise, cooled, washed with water till the latter has no acid reaction, and dried. (*b*) Calcine 11 parts common salt with 25 parts green sulphate of iron; well wash with water, dry, and powder. (*c*) The finest Indian red or "crocus" usually undergoes a second calcination at a higher temperature.

Madder Lake.—(*a*) Tie 2 oz. madder in a cloth, beat it well in a pint of water in a stone mortar, and repeat the process with about 5 pints of fresh water till it ceases to yield colour; boil the mixed liquor in an earthen vessel, pour into a large basin, and add 1 oz. alum dissolved in 1 pint boiling water; stir well, and gradually pour in 1½ oz. of strong solution of carbonate of potash; let stand until cold, pour off the yellow liquor from the top, drain, agitate the residue repeatedly in 1 qt. boiling water, decant, drain, and dry. (*b*) Add a little solution of acetate of lead to a decoction of madder, to throw down the brown colouring matter; filter, add solution of tin or alum, precipitate with solution of carbonate of soda or potash, and proceed as before. (*c*) Macerate 2 lb. ground madder in 1 gal. water for 10 minutes; strain and press quite dry; repeat a second and third time, and add to the mixed liquors ½ lb. alum dissolved in 3 qt. water; heat in water-bath for 3–4 hours, adding water as it evaporates; filter first through flannel, and when cold enough through paper; add solution of carbonate of soda as long as precipitate falls; wash the latter till the water comes off colourless, and dry.

Red Chalk or Reddle.—An earthy red hæmatite, found in all countries and most geological formations.

Red-lead.—This is prepared on the large scale by the oxidation of metallic lead in a reverberatory furnace with two fire hearths covered by an arched roof, situated at the extreme end, separated from the middle hearth, in which the lead lies, by fire-bridges, and fed with coke. The lead, about 10 per cent. being hard, is worked about by an iron tool as soon as melted, the "massicot" or protoxide formed being constantly pushed to the side. The temperature must be kept at low redness, or the oxide will melt. The treatment is sustained for 24 hours; the massicot is then removed, ground, and levigated, and again exposed in the furnace to the same heat for 48 hours, or till it exhibits a bright-red colour on cooling. The furnace is then closed, and allowed to cool as slowly as it will. The product is "minium" or "red-lead."

Vermilion.—(*a*) Melt 1 part sulphur, and gradually add 5–6 parts mercury, continuing the heat till the mixture swells up; then cover the vessel, remove it from the fire, and when the contents are cold, reduce to powder, and sublime in a closed vessel, so placed in a furnace that the flames reach about half the height. Gradually increase the heat till the lower part of the subliming-vessel becomes red-hot; break the cold sublimate, grind in water to fine powder, sift, and dry. It is a black sulphide of mercury. This, reduced to powder, and sublimed, gives a filamentous mass of violet hue, appearing scarlet on trituration. (*b*) Grind together 300 parts mercury and 114 parts flowers of sulphur for some hours, and gradually add 75 parts caustic potash dissolved in 450 parts water; continue the grinding for some time longer, and gently heat the mixture in an iron vessel, first stirring constantly, afterwards at intervals, keeping the temperature as nearly as possible at 46° (115° F.), and renewing the water as evaporated. When reddening commences, increased care is needed, and when the colour is nearly fine, the heat must be maintained at a lower degree till a rich colour is produced. Every precaution must be taken against inhaling the vapours. (*c*) To a mixture of 4 parts hyposulphite of soda and 4 parts sulphate of zinc in dilute solution, add drop by drop a solution containing 1 part corrosive sublimate. Heat the whole gently for 60 hours at 45°–55° (112°–130° F.).

WHITES. *Alum White.*—Dry mix 2 lb. powdered alum, 1 lb. honey; powder, calcine to whiteness in a shallow dish, cool, wash, and dry.

Chinese White.—Mix finely-ground zinc white into a cream with mucilage of gum tragacanth, grinding with a glass muller.

Permanent White.—Precipitate sulphate of barium from the chloride by adding dilute sulphuric acid.

Spanish White.—The softest and purest white chalk, elutriated, balled, and dried.

Sulphate of Lead.—Precipitate the pigment by adding dilute sulphuric acid to an acetic or nitric acid solution of litharge; wash and dry. The clear liquid may be used indefinitely.

Whiting.—Ground chalk, balled and dried.

White-lead.—White-lead or carbonate of lead is made by placing metallic lead in contact with acetic acid in open earthenware vessels, and covered with tan, a number of these vessels forming a "stack," and the whole remaining thus for about 11 weeks, when the lead becomes completely carbonized. The stack is then pulled down, and the carbonate of lead is ground and dried. Many mixtures of white-lead and chalk are sold under fanciful and misleading names.

Wilkinson's White.—Litharge is ground with sea-water till it ceases to whiten, and is then washed and dried.

Zinc White (Griffiths').—Chloride or sulphate of zinc is precipitated by means of a soluble sulphide—sodium, barium, and calcium sulphides have been used—and precautions are taken that no iron present is precipitated. The precipitate is collected, dried, and calcined for some time at cherry-red heat, with careful stirring. It is raked out while hot into vats of cold water, then levigated and dried. It is an oxysulphide of zinc.

YELLOWS. *Chrome Yellow.*—(*a*) Add a filtered solution of nitrate or acetate of lead to a filtered solution of neutral chromate of potash so long as a precipitate falls; collect this, wash with soft water, and dry in security from sulphur-tainted air. (*b*) Dissolve acetate of lead in warm water, and add sufficient sulphuric acid to convert it into sulphate; decant the clear liquid, wash the residue with soft water, and digest with agitation in a hot solution of yellow (neutral) chromate of potash, containing 1 part of this salt for every 3 parts sulphate of lead; decant the liquid, and drain, wash, and dry the precipitate.

Gamboge (FR., *Gomme Gutte*; GER., *Gutti, Gummigutt*).—Gamboge is a product of several trees of E. Asia: viz., *Garcinia Morella* var. *β. pedicellata* [*G. Hanburyi*], a native of Cambodia, the province of Chantibun in Siam, the islands on the E. coast of the Gulf of Siam, and the S. parts of Cochin China; *G. Morella*, growing in the moist forests of Ceylon and S. India; and *G. pictoria*, of S. India, by some considered identical with *G. Morella*. *G. travancorica*, of the southern forests of Travancore and the Tinnevelly Ghâts, is capable of affording small supplies of the pigment for local use, but not for export. (See also Resinous and Gummy Substances—Gamboge.)

When the rainy season has set in, parties of natives start in search of gamboge-trees, and select those which are sufficiently matured. A spiral incision is made in the bark on two sides of the tree, and joints of bamboo are placed at the base of the incision so as to catch the gum-resin as it exudes with extreme slowness during a period of several months. It issues as a yellowish fluid, but gradually assumes a viscous and finally a solid state in the bamboo receptacle. It is very commonly adulterated with rice-flour, and the powdered bark of the tree, but the latter imparts a greenish tint. Sand is occasionally added. The product from a good tree may fill three bamboo joints, each 18–20 in. long and 1½ in. in diameter. The trees flourish on both high and low land. Annual tapping is said to shorten their lives, but if the gum-resin is only drawn in alternate years, the trees do not seem to suffer, and last for many years. Dr. Jamie, of Singapore, who has gamboge-trees growing on his estate, says that they flourish most luxuriantly in the dense jungles. He considers the best time for cutting to be February–April. The filled bamboos are rotated near a fire till the moisture in the gamboge has evaporated sufficiently to permit the bamboo to be stripped from the hardened gum-resin. The gamboge is secreted by the tree chiefly in numerous ducts in the middle layer of the bark, besides a little in the dotted vessels of the outermost layer of the wood, and in the pith. It arrives in commerce in the form of cylinders, 4–8 in. long and 1–2½ in. in diameter, often more or less rendered shapeless. When good, it is dense, homogeneous, brittle, showing conchoidal fracture, scarcely translucent, and of rich brownish-orange colour. Inferior qualities show rough, granular fracture, and brownish hue, and are sometimes still soft. The pigment consists of a mixture of 15–20 per cent. gum with 85–80 per cent. resin. It reaches Europe from Cambodia by way of Bangkok, Saigon, and Singapore. The exports from Singapore in 1877 were 240 *piculs* (of 133⅓ lb.); from Bangkok in 1875, 346 *piculs*; from Saigon annually, 30–40 *piculs*. Saigon, in 1879, received 27 *piculs*, valued at 12*l*. a cwt., from Cambodia.

Naples Yellow.—(*a*) Mix 3 lb. powdered metallic antimony, 1 lb. oxide of zinc, and 2 lb. red-lead; calcine, grind fine, and fuse in a closed crucible; grind the fused mass to fine powder, and wash well. (*b*) Grind 1 part washed antimony with 2 parts red-lead to a stiff paste with water, and expose to red heat for 4–5 hours.

Orpiment or King's Yellow and Realgar.—See pp. 339–340.

Yellow Lakes.—(*a*) Boil 1 lb. Persian berries, quercitron-bark, or turmeric, and 1 oz. cream of tartar, in 1 gal. water till reduced to half; strain the decoction, and precipitate by solution of alum. (*b*) Boil 1 lb. of the dyestuff with ½ lb. alum in 1 gal. water, and precipitate by solution of carbonate of potash. (*c*) Boil 4 oz. annatto and 12 oz. pearlash in 1 gal. water for ½ hour; strain, precipitate by adding 1 lb. alum dissolved in 1 gal. water till it ceases to produce effervescence or a precipitate; strain, and dry.

Paint (Fr., *Peinture*; Ger., *Anstrichfarbe*).—"Paint" consists essentially of two parts, (1) the vehicle or medium, and (2) the pigment (see Pigments). In the case of oil-paints, a third substance becomes necessary, to facilitate the drying or solidification of the vehicle; this is termed a "drier." A perfect vehicle should mix readily with the pigment, forming a mass of about the consistency of treacle. It should itself be colourless, and have no chemical action upon the pigments with which it is mixed. When spread out in a thin layer upon a non-porous substance, it should solidify, and form a film not liable to subsequent disintegration or decay, and sufficiently elastic to resist a slight concussion.

Unfortunately, we possess no vehicle which complies with all these conditions; those which most nearly approach them are the drying oils (see Oils and Fatty Substances, p. 1467). The use of oil in painting is said to have been invented in the 14th century, and, in a short time, it reached a considerable degree of perfection. We have only to compare a van Eyck with a painting by a modern master, Turner, for instance, to see that even the best of recent painters have not succeeded in giving to their works that durability which the originators of the method attained. All organic substances are liable to a more or less rapid oxidation, especially if exposed to light and heat. Oil is no exception to this rule; but it seems that, in its pure state, it is much more durable than when mixed with other substances. Although ground-nut- and poppy-oils (see pp. 1391, 1409) are sometimes employed by artists where freedom from colour is essential, yet linseed-oil (see p. 1393) is the vehicle of by far the larger proportion of paint used both for artistic and general purposes.

Oil-paint appears to have been unknown to the ancients, who used various vehicles, chiefly of animal origin. One of these, which was in high repute at Rome, was the white of eggs beaten with twigs of the fig-tree. No doubt the indiarubber contained in the milky juice exuding from the twigs contributed to the elasticity of the film resulting from the drying of this vehicle. Pliny was aware of the fact that when glue is dissolved in vinegar and allowed to dry, it is less soluble than in its original state. Many suggestions have been made in modern times for vehicles in which glue or size plays an important part. In order to render it insoluble, various chemicals have been added to its solution, such as tannin, alum, and a chromic salt. None of these vehicles, however useful for special purposes, has become sufficiently well known to warrant description here.

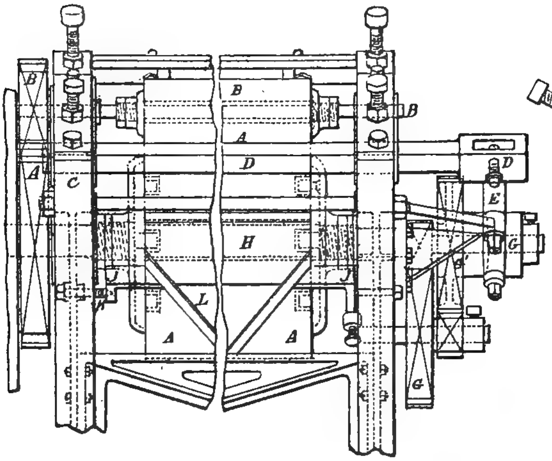
Linseed-oil, to be suitable for painting, must dry well. The test described in the article on Floorcloth (see p. 1002) will indicate whether this be the case or not. Another reliable test is to cover a piece of glass with a film of the raw oil, and to expose it to a temperature of about 38° (100° F.). The time which the film requires to solidify is a measure of the quality of the oil. If the oil has been extracted from unripe or impure seed, the surface of the test-glass will remain "tacky" or sticky for some time, and the same will happen if the oil under examination has been adulterated with either an animal or vegetable non-drying oil.

Until recently, linseed-oil was frequently adulterated with cotton-seed-oil (see p. 1385), extracted from the waste seeds of the cotton-plant. Where the admixture was considerable, it could easily be detected by the sharp, acrid taste of the cotton-seed-oil. Now, however, means have been found for removing this disagreeable taste, and the consequence has been that cotton-seed-oil is so largely used for adulterating olive-oil, or as a substitute for it, that its price has risen above that of linseed-oil. Another adulterant which is rather difficult to detect is rosin. Oil containing this substance is thick, and darker in colour than pure oil. When the proportion of rosin is considerable, its presence may be ascertained by heating a film of the oil upon a metallic plate, when the characteristic smell of burning rosin will be perceptible. When the percentage of rosin is too small for detection in this manner, a film of the oil should be spread upon glass and allowed to dry. When quite hard, the film should be scraped off, and treated with cold turpentine, which will dissolve any rosin which may be present, without materially affecting the oxidized oil. The presence of rosin may also be detected by the following simple chemical test. The oil is boiled for a few minutes with a small quantity of alcohol (sp. gr. 0·9), and is allowed to stand until the alcohol becomes clear. The supernatant liquid is then poured off, and treated with an alcoholic solution of acetate of lead. If the oil be pure, there will be but a very slight turbidity, while the presence of rosin causes a dense flocculent precipitate. Should linseed-oil be adulterated with a non-drying oil, it will remain sticky for months, when spread out in a thin film upon glass or any other non-absorbent substance.

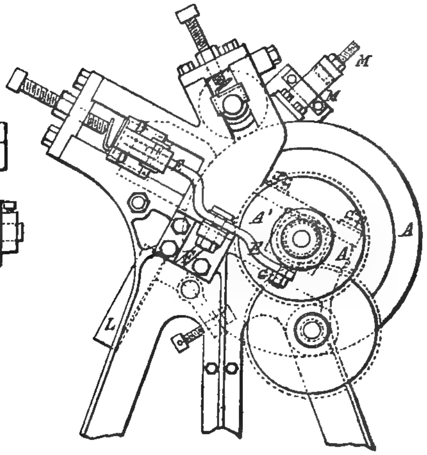
The sp. gr. of linseed-oil is, in some cases, of value in estimating its quality; but, as the variations are slight, it would be difficult to detect them in so thick a liquid by means of an ordinary hydrometer. A simple method of obtaining an approximate result is to procure a sample of oil of known good quality, and to colour it with an aniline dye. A drop of this tinted oil will, when placed in the oil to be tested, indicate, by its sinking or swimming, the relative density of the liquid under examination. Freshly-extracted linseed-oil is unfit for making paint. It contains water and organic impurities, respecting the composition of which little is known, and which are generally termed "mucilage." By storing the oil in tanks for a long time, the water and the greater part of the impurities are precipitated, forming at the bottom of the cistern a pasty mass known as "foots." To accelerate the purification of the oil, and to remove at least a portion of the colouring matter, various methods are in use. The action of sulphuric acid upon linseed-oil is not so favourable as upon other oils. It is, however, sometimes employed, in the proportion of 2 parts of a mixture of equal volumes of commercial sulphuric acid and water to 100 parts of oil. The dilute acid is poured gradually into the oil, and the mixture is violently agitated for several hours. It is then run into tanks, and allowed to settle. A concentrated solution of chloride of zinc has been substituted for sulphuric acid in the proportion of about 1½ per cent. of the weight of the oil. When the reaction is complete, steam or warm water is admitted into the liquid, in order to clarify it. Oil treated in this way loses a considerable proportion of the colouring matter which it originally contained. When the oil is to be used for white paint, it is sometimes bleached by exposing it to the action of light. On a large scale, this is done by placing it in shallow troughs, lined with lead and covered with glass. The lead itself appears to have some influence upon the bleaching of the oil, for the decoloration is not so rapid if the troughs be lined with zinc. For small quantities, a shallow tray of white porcelain or earthenware, similar to those in use for photographic purposes, gives very good results, the white surface increasing the photo-chemical action. It is not quite clear whether the presence of water accelerates the bleaching of oil by this method; some manufacturers consider its presence necessary, others omit it. Various salts are added to the water, the one most in use being copperas. (See also Oils and Fatty Substances, p. 1461.) However the oil may have been prepared, it will, if kept for a long time, deposit a sediment. At first, this contains mucilage; but the sediment from old oil consists chiefly of the products of decomposition of the oil itself. The presence of oxygen is not necessary for this decomposition; but it is increased by the action of light. Raw linseed-oil dries more slowly than boiled; but the resulting film is more brilliant and durable. Raw and boiled oil are therefore usually mixed in proportions varying according to the time which can be allowed for the paint to dry, or to the properties required of the film. For the ordinary kinds of paint, equal parts of boiled and raw oils are customary. Linseed-oil heated to a temperature of 176½°–204½° (350°–400° F.) dries much more rapidly than in its raw state. The maximum of drying power is, however, obtained by the addition of certain metallic oxides, which not only part with some of their own oxygen to the oil, but also act as carriers between the atmospheric oxygen and the heated liquid. This heating of the oil with oxides is known as boiling, although the liquid is not volatilized without decomposition, as is the case with water. At about 260° (500° F.), bubbles begin to rise in the oil, producing acrid, white fumes on coming into contact with the air. The gas thus given off consists chiefly of vapour of acroleïn mingled with carbonic oxide. There is no advantage in heating the oil to a higher temperature than 176½° (350° F.). Accurate experiments have shown that the drying properties of the oil are not increased by heating it beyond this point, while its colour is considerably darkened. For the finer qualities of boiled oils, it is essential that the raw oil should have been stored for some time, so that it may be free from mucilage. This mucilage is the chief source of the dark colour of some boiled oils; when heated, it forms a brown substance, which is soluble in the oil itself, and extremely difficult to remove. The oxides usually added to the oil during boiling are litharge or red-lead, the former being preferred on account of its lower price. About 2–5 per cent. by weight of the oxides or driers is gradually stirred into the oil after it has been slowly raised to a temperature of about 149° (300° F.). The stirring should be continued until the litharge is dissolved, or it would cake on the bottom of the pan, and cause the oil to burn. Litharge may even be reduced to a cake of metallic lead when the fire is brisk. Some pans are furnished with stirrers and gearing by which the latter can be worked, either by hand or steam. The material of which the pans are made is either wrought- or cast-iron. Copper pans are sometimes used with the object of improving the colour of the oil. Little is known respecting the chemical reactions which take place during the boiling of oil. Even when the air is excluded during the process, the drying properties are greatly increased, and, if boiled long enough, the oil is converted into a solid substance. The loss of weight which ensues is dependent upon the temperature, and the time during which the operation continues. It is less when the air is freely admitted than if the pan is covered with a hood. The vapours given off by the oil are of an extremely irritating character, and should be destroyed by passing them through a furnace. As their mixture with air in certain proportions is explosive, this furnace should be situated at some distance, and the gases be conducted into it by means of an earthenware pipe. (See also Oils and Fatty Substances, p. 1449.)

T. Holmes' apparatus for grinding pigments is shown in Figs. 1099 and 1100. The granite roller A revolves against a feed-roller B, travelling in the opposite direction, and at a lower speed, by which means, A feeds itself with the material to be ground. The roller A also works against a concave granite block D, to which is communicated a slow reciprocating motion in a direction parallel with the axis of the roller, thus assisting the grinding and equalizing the wear. A "doctor" cleans the surface of A as the pigment accumulates upon it. Brinjes and Goodwin's machine is shown in Figs. 1101, 1102, and 1103. The oil and pigments having been measured or weighed, are placed in the trough *h*. This is provided with stirrers, similar to those in a pug-mill, which are driven by means of the pulley *l*, *m* being a loose pulley; by shifting the strap on to this, the machine can be stopped at once. When the oil has been thoroughly incorporated with the pigment, the mixture is allowed to run through the spout *g* on the roller *a*. Working against *a*, is a second roller *b*, and this in its turn bears upon a third roller *c*. In order to prevent the grooving of the faces of the rollers, which always takes place when they revolve in the same plane, there is an arrangement by which a slight lateral motion is communicated to *b*, in addition to the rotary motion. A pin fixed upon the rigid bracket *k* works in the grooved cam *i*, which is keyed on the shaft of the roller *b*. The grinding power of the machine is considerably increased by this modification. The rollers are worked from the pulley *d*; the loose pulley *e* receives the strap when a pause in the working of the machine becomes necessary. The details of the construction of the grinding-machine are given in Fig. 1103. The rollers *a b c* are constructed of granite or porcelain; for fine grinding, the latter substance is preferable. They are adjusted by means of the screws *g h*. These are furnished with spiral springs, so that should a nail or other hard substance get between the rollers, these can rise in their bearings, letting the nail fall down at the back. The "doctor" or scraper *f* removes the paint from the surface of the roller *c*;

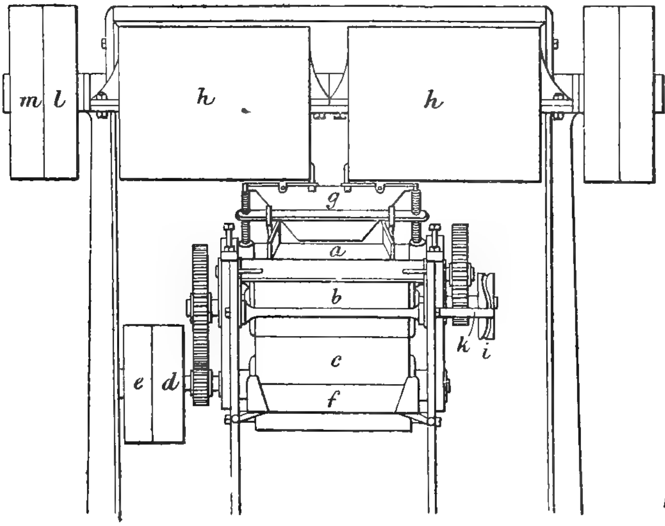
1099.



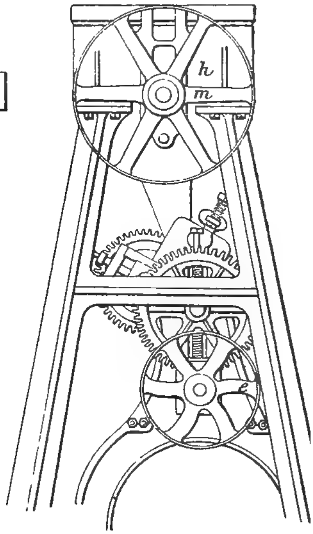
1100.



1101.

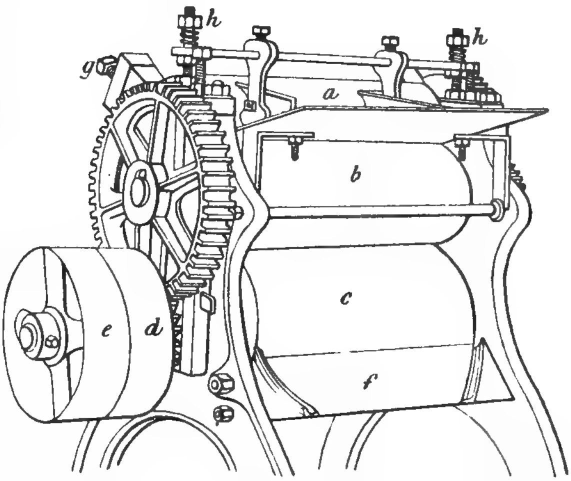


1102.



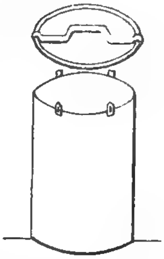
a b are also provided with smaller scrapers, which remove any paint that may cake upon their surfaces. Where extreme fineness is requisite, the paint is again passed through the machine, and this operation is sometimes repeated several times.

1103.



In working these or any other form of grinding-rollers, great care must be taken to clean them thoroughly immediately after use. If the paint be allowed to dry upon the surface of the rollers it is difficult of removal, and interferes with the perfect action of the machine. Should the working parts become clogged with solidified oil, a strong solution of caustic soda or potash will remove it. By means of the same solutions, porcelain rollers may be kept quite white, even if used for mixing coloured paints. Although the colour of most pigments is improved by grinding them finely in oil, yet there are some which suffer in intensity when their size of grain is reduced. Chrome red, for instance, owes its deep colour to the crystals of which it is composed, and when these are reduced to extremely fine fragments, the colour is considerably modified.

1104.



When paint is not intended for immediate use, it is packed in metallic kegs. The construction of these, as made by B. Noakes & Co., is shown in Fig. 1104. For exportation to hot climates, the rim of the lid is sometimes soldered down, a practice which effectually prevents access of atmospheric oxygen. White-lead paint is frequently packed in wooden kegs; these prevent the discoloration sometimes caused by the metal of iron kegs. When paint is mixed ready for use, it will, if exposed to the air, become covered with a skin, which soon attains sufficient thickness to exclude the atmospheric oxygen, and prevent any further solidification of the oil. The paint may be still better protected by pouring water over it, or it may be placed in airtight cans. If it has been allowed to stand for some time, it must be well stirred before using, as the pigments have a tendency not only to separate from the oil, but also to settle down according to their specific gravity.

Of whatever nature the surface may be to which the paint is to be applied, great care must be taken that it is perfectly dry. Wood especially, even when apparently dry, may on a damp day contain as much as 20 per cent. of moisture. A film of paint applied to the surface of wood in this condition prevents the moisture from escaping, and it remains enclosed until a warm sun or artificial heat converts it into vapour, which raises the paint and causes blisters. Moisture enclosed between two coats of paint has the same effect. Paint rarely blisters when applied to wood from which old paint has been burnt off; this is probably due to the drying of the wood during the operation of burning. The first coat of paint applied to any surface is termed the "priming-coat." It usually consists of red-lead and boiled and raw linseed-oil. Experience has shown that such a priming not only dries quickly itself, but also accelerates the drying of the next coat. The latter action must be attributed to the oxygen contained in the red-lead, only a small portion of which is absorbed by the oil with which it is mixed. The drying of paint is to a great extent dependent upon the temperature. At a temperature below the freezing-point of water paint will remain wet for weeks, even when mixed with a considerable proportion of driers; while if exposed to a heat of 49° (120° F.), the same paint will become solid in a few hours. The drying of paint being a process of oxidation, and not evaporation, it is essential that a good supply of fresh air should be provided. When a film of fresh paint is placed with a certain quantity of air in a closed vessel, it does not absorb the whole of the oxygen present; but after a time, the drying process is arrested, and the remaining oxygen appears to have become inert. Considerable quantities of volatile vapours are given off during the drying of paint; these are due to the decomposition of the oil. When the paint has been thinned down by means of turpentine, the whole of this liquid evaporates on exposure to the air. There must, therefore, be a plentiful access of air, both to remove the vapours formed, and to afford a fresh supply of active oxygen. The presence of moisture in the air is rather beneficial than injurious at this stage. Especially in the case of paints mixed with varnish, moist air appears to counteract the tendency to crack or shrink. Under the erroneous impression that the drying of paint is a species of evaporation, open fires are sometimes kept up in freshly-painted rooms. It is only when the temperature is very low, that any benefit can result from this practice; as a rule, it rather retards than hastens the solidification of the oil, which cannot take place rapidly in an atmosphere laden with carbonic acid. The first coat of paint should be thoroughly dry before the second is applied. Acrylic acid is formed during the oxidation of linseed-oil, and unless this be allowed to evaporate, it may subsequently liberate carbonic acid from the white-lead present in most paints, and give rise to blisters. Sometimes a second priming-coat is given; but usually the second coat applied contains the pigment. This, as soon as dry, is again covered by another coat, and subsequently by two or more finishing-coats, according to the nature of the work. Before the first coat is applied to wood, all holes should be filled up. The filling usually employed is ordinary putty. This, however, sometimes consists of whiting ground up with oil foots of a non-drying character. When the films of paint are dry, the oil from the putty exudes to the surface, causing a stain. The best filling for ordinary purposes is whiting ground to a paste with boiled linseed-oil. For finer work, and for filling cracks, red-lead mixed with the same vehicle may be employed. There is no advantage in laying on the paint too thickly. A thick film takes longer to dry thoroughly than two thin films of the same aggregate thickness. Paint is thinned down or diluted with linseed-oil or turpentine. The latter liquid, when used in excess, causes the paint to dry with a dull surface, and has an injurious effect upon its stability. Sometimes the last coat of paint is mixed with varnish, in order to give it greater brilliancy. In this case, special care must be taken that the previous coats have thoroughly solidified, or cracks in the final coat may subsequently appear. The same remark applies when the surface of the paint is varnished. The turpentine with which the varnish is mixed has a powerful action upon the oil contained in the paint, if the latter is not thoroughly oxidized. The exterior of the paint is thus softened, and the varnish is enabled to shrink and crack, especially in warm weather.

The method of applying paint by means of brushes is too well known to need description; but a few words as to the proper treatment of the brushes may not be superfluous. The bristles are frequently fastened together by means of glue or size, which is not perceptibly acted upon by oil, and if brought into contact with this liquid alone, there would be no complaints of loose hairs coming out and spoiling the work. It is a common practice to leave the brushes in a paint-pot, in which the paint is covered with water to keep it from drying. The brushes are certainly kept soft and pliant in this way; but at the same time the glue is softened, and the bristles come out as soon as the brush is used. After use, brushes should be cleaned, and placed in linseed-oil until again required, when they will be found in good condition. Treated in this way, they will wear so much better that the little additional trouble entailed is amply repaid.

W. F. R.

POTTERY (Fr., *Poterie*; Ger., *Töpferwaare*).

The order in which the branches of the subject will be treated is as follows:—Definition and General principles; Raw Materials and their Preparation; Throwing-wheels and Lathes; Kilns or Ovens, and Muffles; the various Wares—Fire-ware, Stone-ware, Earthen-ware, Terra-cotta, Tiles, Porcelain, and China; Processes of Decoration.

Definition and General Principles.—Every ware made of clay, or of a mixture in which clay is the chief ingredient, and hardened by heat, may be regarded as a species of "pottery." There are many varieties of clay (see Clay, pp. 635–40), all of which have been formed by the disintegration of felspathic and silicious rocks, and consist of hydrous aluminic silicate mixed with small and varying proportions of other materials derived from the same sources. A clay adapted to the manufacture of pottery must be plastic, and must become hard under the influence of heat. Plasticity is an attribute of hydrous aluminic silicate, and is developed by the mechanical mixture of this body with a limited quantity of water. Clay is insoluble in water, but may be diffused through it in a state of extreme subdivision, and regains plasticity when the excess of water is removed. If a clay be exposed to a high temperature, artificially produced, and be rendered anhydrous by the removal of water previously held in chemical combination, it can never regain plasticity by mechanical mixture with water.

Hardening is produced (1) by the removal of water mechanically mixed with the clay, (2) by the removal of water, and sometimes of carbonic acid, chemically combined with the clay, (3) by the closer juxtaposition of the particles of the clay, due to the fusion of a part of the ingredients. Some clays, when exposed to the full heat of a pottery-kiln, fuse readily throughout their substance, owing to the presence of other materials in addition to the aluminic silicate. Aluminic silicate is by itself practically infusible, but when exposed to an intense heat in the presence of free silica, together with calcic, sodic, potassic, magnesic, ferric, or ferrous oxides, it unites, wholly or in part, with the silicates formed from these ingredients, to create a readily fusible glass. Most natural clays contain free hydrous silica, together with one or more of the oxides mentioned, and the quantity of aluminic silicate which can be rendered fusible is determined by the quantity of silicate-forming ingredients incorporated with it. Felspar, which is a natural glass, and from whose decomposition, certain clays are formed, is built up of equivalent parts of aluminic silicate and of potassic, sodic, or calcic silicate. The fusibility of a clay is greater or less as its composition approaches or recedes from the proportions observable in felspar.

Solidification necessarily implies contraction. Pure aluminic silicate, when artificially heated, shrinks excessively, and splits into fragments. The purest clays are the most infusible, and at the same time are the most liable to fracture and distortion under the influence of heat. Very few clays in their natural state are free from intermixture with iron. The form in which iron commonly appears is that of the yellow or brown hydrous ferric oxide. The presence of iron in an unburnt clay is often concealed by organic colouring matter; but exposure to a moderate heat destroys the organic matter, and discovers the pink or red colour of the anhydrous ferric oxide.

Certain impure natural clays may be employed in the manufacture of the coarsest descriptions of pottery, coherency being produced either by the plasticity of the clay and the simple removal of mechanically mixed water, as is the case in oriental sun-baked ware; or by the removal of both mechanically and chemically mixed water, together with the incipient fusion of part of the ingredients, provided these results are attained at a low temperature. Resistance to high temperatures, regularity of form, impermeability, purity of colour, and translucency can only be gained by the use of mixtures so constituted that the qualities, which are not supplied by the natural clay, are yielded by materials artificially introduced. A perfect mixture must be sufficiently plastic, when water is added, to facilitate manipulation; sufficiently infusible to resist collapse by fusion, when exposed to the heat requisite to produce hardness; sufficiently stable to resist excessive shrinkage and distortion; sufficiently fusible to become impermeable, and, in some cases, translucent; and sufficiently free from iron when the colour obtained from iron is not wanted, to be colourless or almost colourless after burning. A mixture for pottery is at the best a well-balanced mechanical arrangement, and cannot be regarded or represented as a chemical compound.

The value of the separate materials depends as much upon physical aggregation as upon chemical composition, and their qualities must be determined both by analysis and by direct experiment. Analyses and experiments must be constantly repeated, inasmuch as the materials consist principally of natural products, and not of artificially produced chemicals. As the mixtures for different wares must vary according as the physical or chemical natures of the raw materials vary, recipes and even analyses of wares are of little practical use. For white or light coloured goods, as well as for those intended to withstand high temperatures, pure clays are used. The distortion and fracture, due to excessive or irregular shrinkage, to which wares made from pure clays are especially liable, may be considerably reduced by the introduction of an infusible anhydrous substance, in such proportion as not to interfere materially with the plasticity of the clay. The substances employed are, for common ware, sand or a proportion of a grittier and less fusible clay; for fire-ware, graphite or burnt fire-clay; for domestic and sanitary ware, calcined flint; and for ornamental ware, baric sulphate or calcic phosphate. If a mixture be manipulated in a state of liquidity, and the resultant ware be brought to a vitreous condition by heat, the total shrinkage may amount to as much as 30 per cent. If wares are required to be impermeable or translucent, the infusibility of a pure clay, and the increase of infusibility caused by the introduction of an infusible foreign substance, must be compensated by the addition of a proportion of a glass-forming material of felspathic nature. By varying the proportion of this ingredient, wares may be obtained in every stage between porosity and translucency, and proportionately differing from or resembling glass in their physical properties.

The nature of wares depends in a great measure upon the temperature to which they are exposed. With a gradually increasing temperature, the same mixture may successively assume the texture and character of sun-baked ware, terra-cotta, stone-ware, porcelain, and glass. Intense and prolonged heat will convert the external crust of a Stourbridge-clay (see Clay) crucible into translucent porcelain. In artificial mixtures, the proportion of glass-forming ingredients is purposely kept so low that the surface of the ware, even after exposure to the full heat of the kiln, remains rough and absorbent. For most decorative, domestic, and sanitary purposes, it is necessary to cover this surface with a smooth, non-absorbent film; this result is practically gained by covering the surface of the ware with an extremely thin layer of glass. For certain common wares, whose composition renders them unfitted to resist a high temperature, and which would otherwise remain porous and incoherent, a film of glass serves the double purpose of a glaze and a bond.

Wares are coloured by metallic oxides. The common red, brown, and yellow tints are due to ferric oxide, whether naturally present or artificially introduced. The colours which may be obtained by the use of iron compounds depend upon the temperature to which the wares are exposed, the atmosphere in which they are burnt, and the constituents of the ware. If the temperature be low, and free access of air be permitted, the ware is tinted by the natural colour of the anhydrous ferric oxide; if, however, there be present an excess of calcic or magnesic oxides, the tints are greatly modified. If organic matter be present in large quantity, or if the ware be exposed to a strongly reducing atmosphere, the ware may be tinted black or grey, owing to the conversion of the ferric into magnetic oxide. At a high temperature, in an oxidizing atmosphere, and in the presence of glass-forming materials, the substance of the ware will be tinted yellow by the colour of the glass with which the ferric oxide has combined. If, however, the ferric oxide be reduced to the ferrous condition, the ware will be tinted green. All the metallic oxides which are used for colouring glass (see Glass, pp. 1083–4) may be used for pottery. If the temperature be low, or if no glass be formed in the ware, it will be coloured by the natural colour of the anhydrous oxide; if, on the other hand, the temperature be high, and if a glass be formed, the ware will receive the same colour as a glass would receive under similar circumstances. Advantage is taken of this fact to neutralize, by the addition of a minute trace of cobaltic oxide, the tints produced by ferric or ferrous oxides. The infusible substances introduced into mixtures in order to reduce shrinkage, being generally of a white colour, heighten the whiteness of the wares produced.

For all manipulative processes, it is necessary to reduce the raw materials to a fine state of subdivision, either by grinding, or by diffusion in water. Wares whose different ingredients have been reduced to different degrees of fineness, even though the difference be imperceptible, are rendered more solid, and are better fitted to resist the temperature of the kiln, as well as the changes of temperature to which they may be afterwards exposed. Wares are produced from suitable mixtures (1) in the state of dry or slightly moistened powder, (2) in a plastic condition, (3) in a liquid state. In all processes of manipulation, care must be taken that the body of the ware be homogeneous throughout. Inequality of pressure, by disturbing the homogeneity of the substance, is a fruitful source of disfigurement and fracture. Although no trace of irregularity may be apparent in the unburnt ware, it will, if present, be discovered by the ordeal of fire. After manipulation, wares are gradually dried, and solidified by exposure to heat in suitably-constructed kilns. Glazing and the different processes of decoration generally require one or more additional firings.

The average proportion of fusible to infusible ingredients in different wares is approximately illustrated in the following table of the results of analyses:—

						Porcelain.					
	Hessian Crucible.	Stone-ware and Terra-cotta.	Earthenware.	English China.	Parian.	Chinese White body.	Glaze of same.	Japanese Egg-shell.	Sèvres Body.	Sèvres Glaze.	Berlin.
Silica	71·00	74·00	71·00	38·88	54·80	75·0	67·5	78·8	58·0	74·3	71·3
Alumina	25·00	22·04	26·00	21·48	36·21	17·8	14·5	17·8	34·0	18·3	23·7
Ferric oxide ..	4·00	2·00		10·06		0·2	2·5	0·6			1·7
Calcic oxide ..		0·60				1·0	10 0	0·2	4·5	0·4	0·6
Magnesic oxide		0·17				0·5	1·0	trace	0·5	0·2	
Alkali: Sodic oxide ..			3·00		8·80	1·0	0·5	2·0			0·6
Alkali		1·06		2·14							
Alkali: Potassic oxide ..						4·5	4·0	0·2	3·0	6·5	2·0
Calcic phosphate				26·44							

Raw Materials.—The materials used in the manufacture of pottery may be divided into four classes:—(I) Plastic clays; (II) glass-forming materials, used either in the body or the glaze; (III) indifferent substances; (IV) colouring agents.

Class I.—Kaolin, Cornish or China clay (see p. 635); artificial Cornish clay of Belleek (see p. 639); Fire-clay (see p. 638).

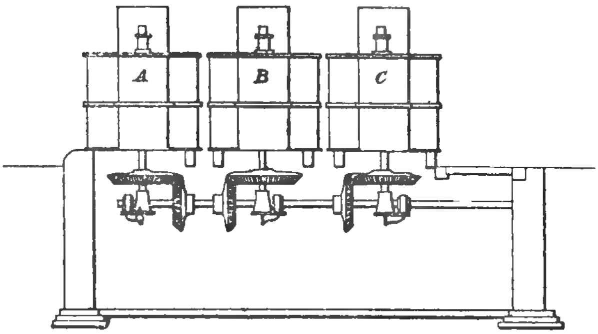
The "blue," "ball," or "pottery" clay of Dorsetshire and Devonshire is highly plastic. The upper beds of this clay frequently contain a large proportion of sand, and furnish a body which, without further admixture, is suited for the manufacture of ordinary stone-ware. The finest quality of the clay is found at a considerable depth; it is of a uniform blue-grey colour due to organic matter, is unctuous, and free from grit; it mixes with water with some difficulty; when treated with acids, no effervescence takes place; when subjected to a moderate heat, it becomes white, hard, and but slightly absorbent; with an intense heat, it is rendered so hard as to resist scratching with a steel point, assumes a yellow tint, and becomes non-absorbent. There is but a trifling proportion of iron intimately mixed with the clay, although nodules of pyrites are of common occurrence; the free silica present in the clay is in a state of exceedingly fine division.

Table of Results of Analyses of Samples of Different Clays.

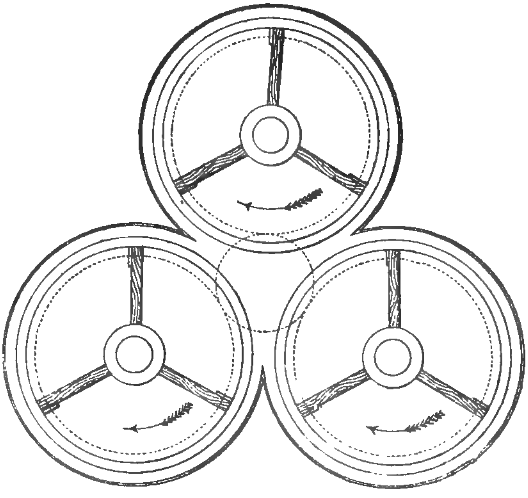
	Kaolin Cornish.	Kaolin S. Yrieix.	Stourbridge Fire-clay.	Dorsetshire Clay.	Devonshire Clay.
Silica	46·32	48·37	64·10	48·99	52·06
Alumina	39·74	34.95	23·15	32·11	20·38
Iron	0·27	1·26	1·85	2·34	2·37
Calcic oxide	0·36	—	..	0·43	0·43
Magnesic oxide	0·44	trace	0·95	0·22	0·02
Sodic and potassic oxides	12·67	2·40	..	3·31	2·29
Water		12·62	10·00	11·96	12·83

Preparation of Clays.—All clays, after extraction, are heaped up in the open, and exposed to the weather for as long a period as possible. Lengthened exposure tends to disintegrate the mass of the clay, and it is certain that ware containing clay which has been long exposed, is less liable to shrinkage than if the clay has been mixed with the other ingredients of the ware without previous exposure. In China and in France, it is customary to preserve the prepared mixtures for a long period; whereas in England, directly the clay has been incorporated with the other necessary substances, the mixture is considered ready for use. Fire-clay and the dry sandy clay derived from the upper strata of the blue-clay deposits, are prepared for use by grinding; kaolin and superior blue clay, by diffusion in water. The mills employed for grinding dry clays resemble ordinary mortar-mills. Diffusion is effected by stirring the masses of clay in tanks of water, by means of paddles worked by hand or machinery. The process of mixing the clay and water is known as "blunging," and the machines in which the process takes place, as "blungers." The simplest form of machine-blunger is a horizontal wheel, with paddles attached to the circumference, revolving in a round or octagonal pan. Power is communicated to the shaft of the wheel from beneath by suitable gearing. Fig. 1105 represents three blungers A B C, intended respectively for ball-clay, kaolin, and "shavings" of unburnt ware (which represent the plastic constituents of earthenware), driven as described. Agitation may be increased by fixing projecting perforated arms to the inside wall of the pan, against and through which the clay is driven by the revolution of the paddles. The most recent form of blunger consists of an octagonal cast-iron pan,—the octagonal form aiding the process of disintegration,—with a circular casting to ward off the material from the bearings of a central spindle. To the spindle, are fixed six oblique blades, arranged in accordance with the principle of an archimedean screw. When water and clay have been introduced, and the spindle has been set in motion, the clay is gradually raised to the level of the topmost blade, where it is dashed against splash-boards, and thrown to the bottom of the pan, to be once more raised and rejected, until such time as the mixture is complete. Fig. 1106 is a view of three communicating

1105.



1106.

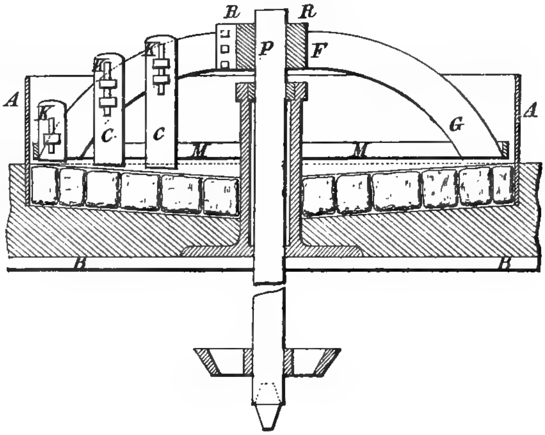


blungers driven from the centre. The pans are so arranged that the mixture is forced to pass successively from one to the other, by which means, friction and agitation of the mixture are increased.

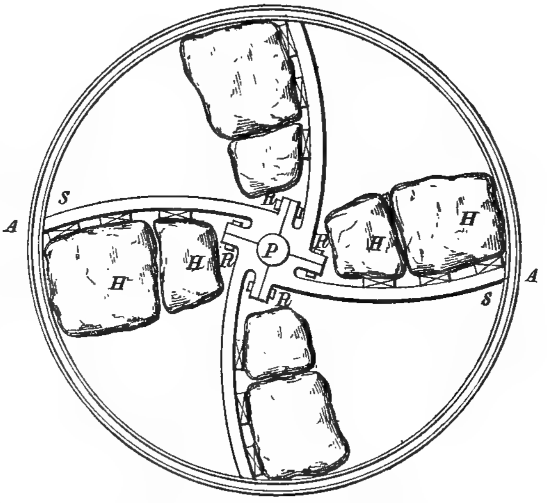
Class II. Glass-forming Materials.—Felspar, which may be regarded as a natural type of a glass (the potassium felspar being represented approximately by the formula $K_2O, Al_2O_3, 6 SiO_2$), is used both as a glaze and as a glass-forming ingredient in the body of porcelain. It is generally obtained from Sweden, in masses of a salmon-red colour. It becomes white when calcined.

Cornish stone is used for almost all English wares, both in the body and the glaze; it is a granite, in which the constituent felspar has been partially decomposed, but which retains sufficient alkaline silicate to render the mass fusible. It is quarried at St. Stephen's, in Cornwall, whence some of the best English kaolin is also derived. Pegmatite is a form of the same rock, but in a more advanced stage of disintegration; whereas granite consists of intermixed crystals of quartz, mica, and felspar, pegmatite retains no mica, and but a trifling proportion of quartz. Felspar, Cornish stone, and pegmatite are exceedingly hard, and are ground and diffused in water by mills of peculiar construction, illustrated in Figs. 1107–8. Fig. 1107 is a vertical, and Fig. 1108 a horizontal section of the mill; the external wrought-iron case or pan A is protected from injury from the grinding stones by an internal ring; B is the floor-level, and P is the shaft driven from below. The base of the pan is paved with blocks of chert, and the pavement slopes from the circumference towards the central shaft. To the shaft, are bolted, by the bolts R, the curved arms S. The shape of the arms F G is shown in Fig. 1107; to these, and to a connecting-bar M, the boards C are fastened, as shown at K. Blocks of chert H are chained to these boards, and are carried round by the arms. When the substance to be ground and the water have been introduced into the pan, and motion has been communicated to the shaft, grinding takes place between the contiguous surfaces of the blocks and the pavement.

1107.



1108.

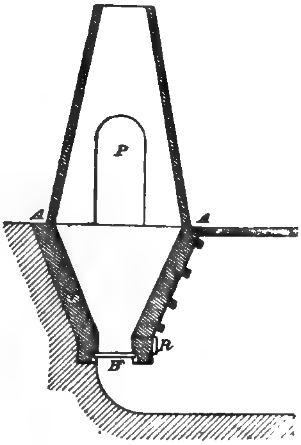


To the glass-forming ingredients already mentioned, must be added the carbonate and oxide of lead, sand, borax, and the carbonates of sodium and potassium.

Class III. Indifferent Substances which do not contribute Plasticity or Translucency.—Flint are obtained from the upper strata of the chalk. Those nodules are preferred which are black, compact, and free from iron and incrustation. When exposed to an intense heat, flint burns to a pure white. The whiteness and stability of the calcined flint are availed of for neutralizing the colour and contraction inherent to clay. Calcination is effected in a kiln similar to that represented in section in Fig. 1109: A is the ground level, with the chimney or cone rising from it; P, the charging-door; B, the grate for supporting the layers of coal and flint introduced through the door P; R, the stoke-hole. The calcined flints are removed by withdrawing the bars of the grate B.

The masses of calcined flint are reduced to powder in a "stamping-mill" or a "crusher." The former consists of a row of vertical, heavily-weighted, iron clubs or stamps, with projections on their upper extremities. These projections are successively caught and released by cogs fixed at intervals upon the surface of a horizontally-revolving cylinder; each stamp is raised and allowed to fall as its projection is caught by or released from a cog, and the flint introduced beneath is gradually pulverized by its descent. The crusher shown in section in Fig. 1110 grinds successive charges of flint between its iron jaws H J. The jaws are opened and shut by mechanism represented in the figure. The flint, reduced to a coarse powder, requires to be reground and mixed with water in a mill with stone runners, whence the mixture issues as a pure white creamy liquid.

1109.



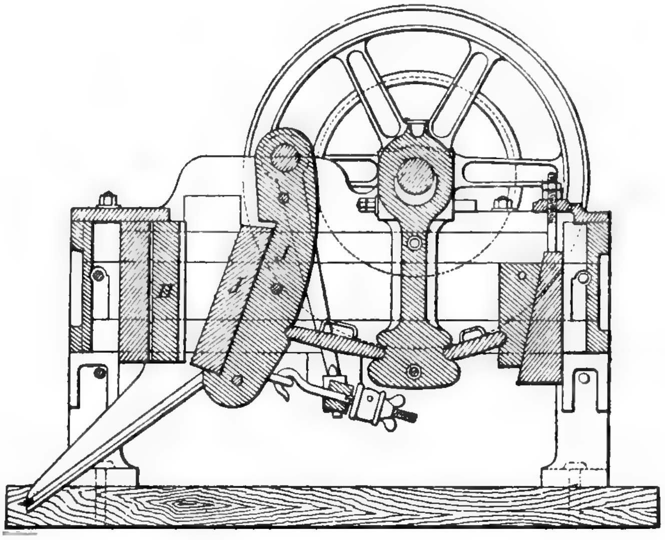
Bone-ash (calcic phosphate) is obtained by the calcination of bones, those being preferred which contain the smallest proportion of oxide of iron. The bones are generally freed from grease by boiling (see p. 1449), and calcined in the same manner as flint. In some cases, however, the grease is allowed to remain in the bones, and to act as an auxiliary fuel. Calcination is considered complete when the bones are perfectly white, and adhere to the tongue. They are crushed and ground with water. Bone-ash is the characteristic ingredient of English china.

Graphite is used in combination with fire-clay, for the manufacture of crucibles, and other apparatus employed in metallurgical operations (see Graphite, pp. 1087–93).

Class IV. Colouring Agents.—These are exclusively metallic oxides and metals (see under Decorative Processes, p. 1597).

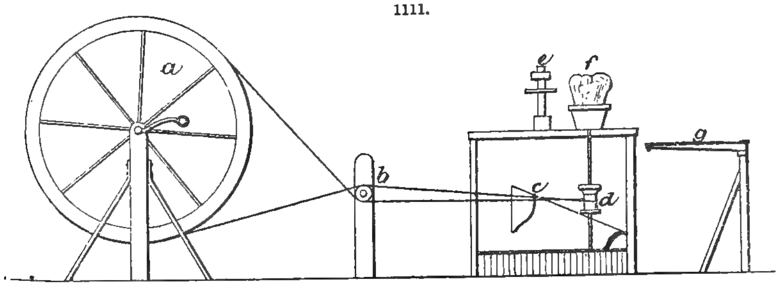
Throwing-wheels and Lathes.—The essential part of a throwing-wheel is a horizontal disc, rigidly fixed to a vertical spindle. Rotary motion may be communicated to the spindle in a variety of ways. Fig. 1111 represents probably the oldest form of throwing-wheel not turned actually by the thrower's hand. The large wheel *a* is turned by an assistant, and communicates a vertical motion to the driving-band *b*. By turning the band, vertical motion is converted into horizontal motion for driving the pulley *d* rigidly attached to the lower part of the spindle. A pedal *c* is shown, which is under the control of the thrower's foot, and which impends over the driving-band. The pulley is conical, and by depressing the pedal, and consequently the band, the thrower can, to a certain extent, regulate the speed of the spindle, and can stop it altogether by throwing the band off the pulley. The speed, however, is mainly regulated by signs and words addressed by the thrower to his assistant. Fig. 1112 shows a wheel which is turned by the pressure of the thrower's foot upon a large horizontal wheel, rigidly attached to the lower part of the spindle.

1110.



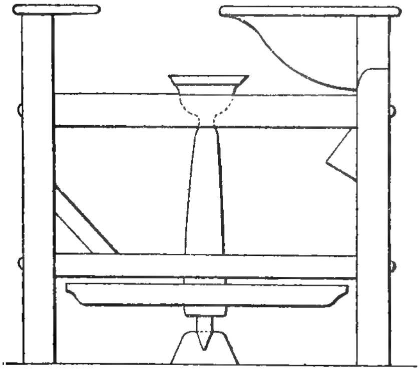
Figs. 1113, 1114 show respectively a throwing-wheel, and a moulding-wheel or jigger-head, both driven by steam power, and in both of which the speed is regulated on the same principle. In Fig. 1113, motion is communicated to the pulley G by a band running upon an overhead drum, which is driven by a steam-engine placed in any convenient position; G revolves in a perpendicular plane, and communicates similar motion to the large solid wheel D through the axle E; H is a friction-wheel, which is in contact with the wheel D, and rigidly attached to the spindle B, which turns the disc C. H can be vertically raised or lowered over the face of the wheel D, by the rod R, turning on the axis L, and counterpoised by the weight S. The thrower sits on the frame A; the motion of the wheel D in contact with the friction-wheel H causes the spindle and disc to revolve.

1111.



By depressing the weight S, the friction-wheel can be raised into a position opposite to the centre of the wheel D, and inasmuch as the speed in the centre of a wheel is less than at its circumference, the speed of the disc may be reduced. In the same manner, by raising the weight, the speed of the disc can be increased. In Fig. 1114, C is the jigger-head, and M is a stirrup, into which the operator can insert his foot, and depress or raise the rod R. The other letters represent the same parts as in Fig. 1113. In Fig. 1115, a throwing-wheel is shown without any seat for the thrower; but his position is such that he can place one foot on the treadle A, which gives an oscillating motion to the cone B, which is driven by a pulley rigidly attached to its shaft, as shown. When B, which is revolving, is shifted from its vertical position, it comes into contact with the cone C, which is fixed to the spindle of the throwing-wheel. The friction of the cone B against the cone C, causes the latter to revolve. The cone B is always at the same speed, but the speed of the cone C, and consequently of the spindle and disc, can be varied at the thrower's pleasure. If the displacement of the cone B be so slight that only its small end comes into contact with the big end of C, the motion of the spindle will be slow; but if the displacement be increased so that the large end of B comes into contact with the small end of C, the velocity of the spindle will be greatly increased.

1112.



1113.

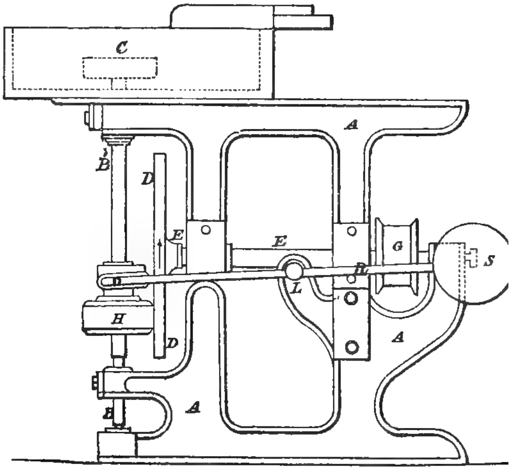
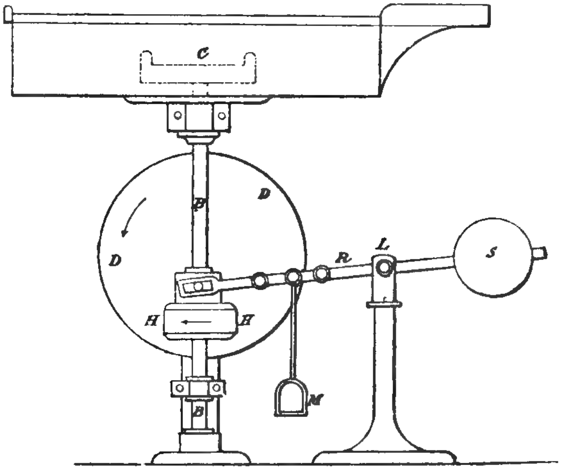


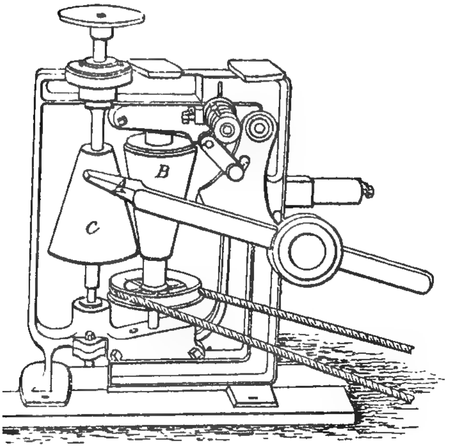
Fig. 1116 represents a lathe, whose speed is regulated upon the same principle as that just described. On the lathe-spindle, are fixed two cones, and running loose on a shaft parallel to it, are two other cones, revolving in opposite directions, and driven by pulleys. When the shaft is exactly parallel to the lathe-spindle, the two sets of cones are distinct, and no motion is communicated; but when the shaft, together with the loose cones, is turned at a slight angle to the lathe-spindle, which is accomplished by means of an arrangement of levers under the control of the turner's foot, either cone can be brought into contact, and the speed be varied at will. The old system of applying motion to the turner's lathe, and one which unfortunately is still in vogue, is by means of a large treadle worked by an assistant, who is usually a young woman. In modern potteries, the wheels, lathes, and jiggers are, as far as possible, so arranged that they can all be driven by one endless band, passing round the whole building in which they are placed, and driven by steam power. The band may be either above or below the floor.

1114.

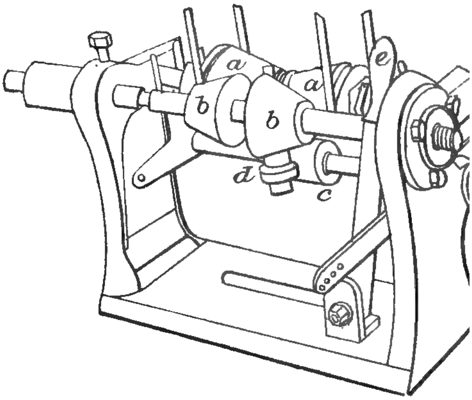


Kilns or Ovens, and Muffles.—The two important processes for which ovens are required are (1) the hardening of ware, and (2) the fixing of glaze upon its surface. Wares, after manipulation, and a preparatory course of drying, are inserted in deep fire-clay trays ("saggers"), which are piled up in columns on the floor of the oven. After exposure to the heat of the oven, the ware is found to be hard, but, at the same time, porous in greater or less degree, and possessing a surface which is rough and usually absorbent. An absorptive or rough surface is well suited to receive certain forms of decoration, and especially the glaze which is applied in a liquid state. The arrangement of an oven for firing the glaze is similar to that used for hardening the ware, and differs only in size, the hardening-oven being considerably larger. The latter is technically termed the "biscuit-oven," and the ware after burning is said to be "biscuit-ware;" whereas the oven for firing the glaze is generally called the "glost-oven." In the glost-oven, the interstices between the saggers are luted with plastic clay. The old-fashioned biscuit- or glost-oven consists mainly of a dome, situated within a large conical chimney or "hovel." Round the base of the dome, or oven proper, project 8–12 fire-places, with ash-pits sunk below the level of the ground-line. The fire-places are charged from above, and the openings for charging can be closed at will. The flame and heat from each fire-place enter the oven by two flues, the one vertical, the other horizontal; dampers inserted in the outside walls of the vertical flues regulate the introduction of air. The horizontal flues pass under the floor of the oven, and converge to a vertical common central flue, by which the heat enters the oven. The smoke and products of combustion pass through openings in the upper part of the dome, into the chimney or hovel which surrounds it. In Robey's oven, the flame and heat enter by horizontal flues converging to a central opening in the floor, but the dome being closed during the process of firing, they are reflected back upon the saggers, and the products of combustion pass away by apertures

1115.



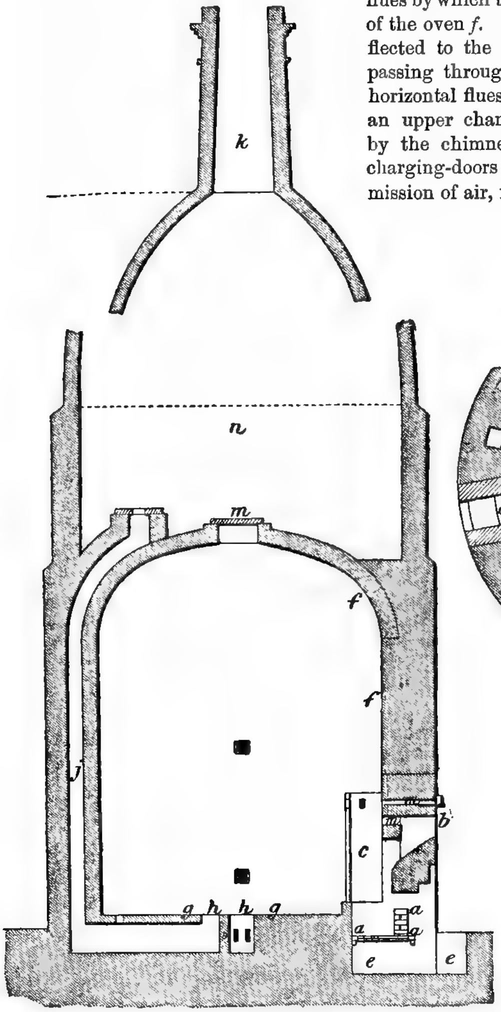
1116.



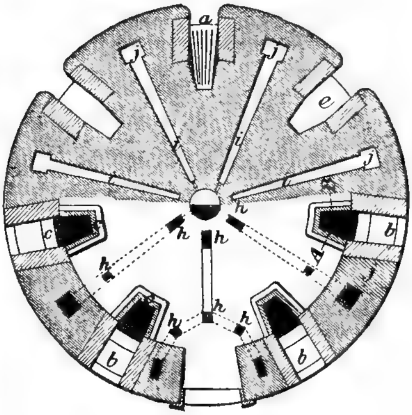
in the floor between the central opening and the wall of the oven, these apertures communicating with a circular flue, which discharges itself into an external chimney-shaft.

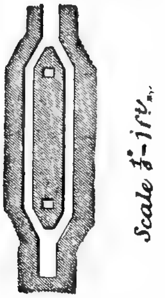
Figs. 1117 to 1119 illustrate the construction of Minton's patent oven. The figures represent respectively a vertical section of the oven, a horizontal section through the fire-places and the underground horizontal flues, and a section of an upright flue where it meets the trial-holes. The grate-bars *a* have temporary brick partitions to prevent the fuel falling into the ash-pit *e*; *b* are the doors by which the fuel is introduced; *c*, the fire-places and vertical flues by which the flame is directed towards the upper part of the oven *f*. The vent *m* being closed, the heat is reflected to the floor *g*, and the products of combustion, passing through several openings in the floor *h*, into the horizontal flues *i*, escape through the vertical flues *j*, into an upper chamber *n*, and thence into the atmosphere by the chimney *k*. The small openings *m* above the charging-doors act as dampers for regulating the admission of air, necessary to ensure complete combustion. The upper vent *m*, as well as the flue communicating with central vent *h*, is opened when the firing has been completed, to assist in cooling the ware. The upper chamber helps to equalize the draughts of the different fire-places. The advantages claimed for this oven are (1) saving of space by doing away with the external hovel, as well as the projecting fire-places, (2) saving of fuel, (3) complete combustion of the fuel, and consequent prevention of nuisance.

1117.



1118.

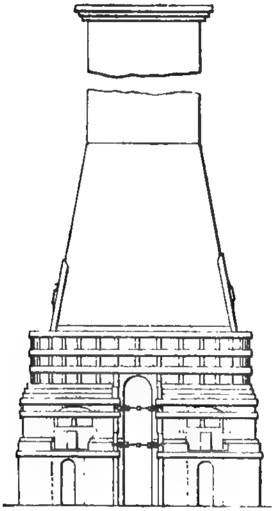




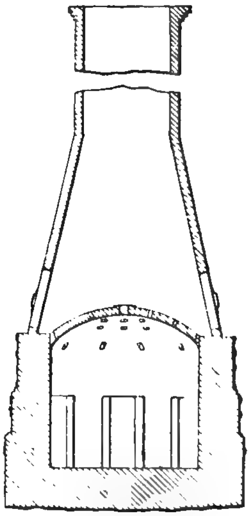
1119.

For ware which is hardened and glazed in one firing, the glaze being produced by the combination of volatilized salt with the material of the surface of the ware, ovens are constructed with ports which can be opened or closed at will, or the openings in the crown of the oven are utilized as well as the fire-places for the introduction of the salt. Wares glazed by this process are exposed without saggers to the full heat and flame of the fires. Coal with a small proportion of coke is used as fuel. Figs. 1120 to 1123 represent respectively the exterior, vertical section, and horizontal sections through the fire-places, and through the crown of the oven, showing the apertures or ports, of an ordinary up-draught salt-glaze oven. In Figs. 1124 to 1126, arrangements are shown by which an up-draught oven may be converted into a down-draught oven. The burning-chamber *a* is enclosed at the top by the arch *b*, the apertures in which have been closed by tiles, but may be opened for the introduction of salt; *c* are the fire-places, the flame entering the oven indirectly through the

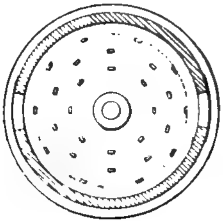
1120.

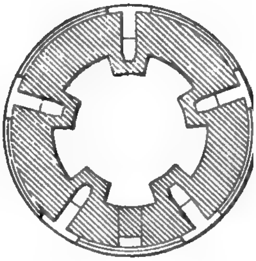


1121.



1122.



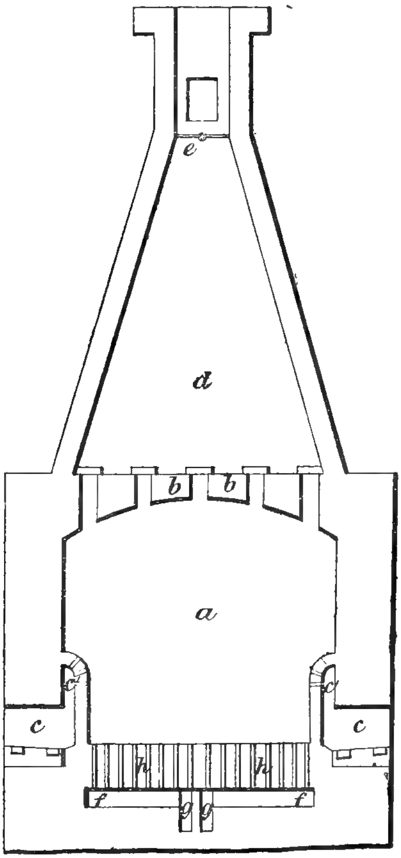


1123.

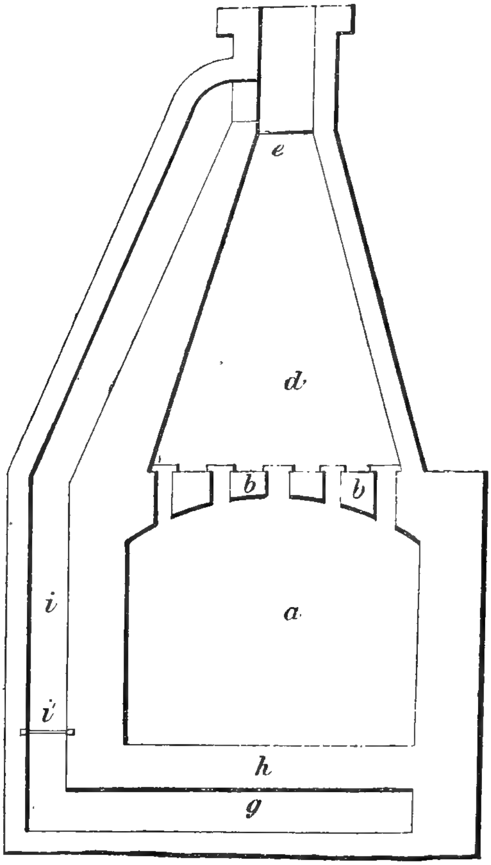
small apertures in the vertical flues *c*. Fire-clay blocks, placed on end on the floor of the oven to support the ware, are so arranged as to leave intervals for the escape of the reflected gases into the underground horizontal flues *f*, whence they escape through the two horizontal flues *g* into the flue *i*, which enters the chimney above a valve *e*, so as to allow the space D to be used for a drying-room or for burning terra-cotta.

Figs. 1127, 1128, and 1129 illustrate the application of the principle of Siemens' gas-furnaces to the burning of pottery. Fig. 1127 shows a longitudinal section through four connected ovens; Fig. 1128, a sectional plan of the same; and Fig. 1129, a transverse section of the fourth oven. The objects represented in the ovens are bricks, but pottery can be burnt with equal facility. The four ovens A^1 A^2 A^3 A^4 are connected with the gas-generator, the air, and the chimney, in the following manner. The bottom of A^1 communicates with the top of A^2 through the passage a^1; the bottom of A^2 with the top of A^3 by a^2; the bottom of A^3 with the top of A^4 through the passage a^3; and the bottom of A^4 with top of A^1 by passages x and a^4. Slides c^1–c^4 for dampers are provided in each of the passages a^1–a^4, but there is only one damper for all the four passages, and it is consecutively placed in each. An underground flue B^4 (Fig. 1129) passes from the gas-generator along the front of all four ovens, before each of which it opens into the vertical shafts D^1–D^4, which are closed at the top, and from which, branch the pipes E^1–E^4. These pipes enter the centre of the side of each oven, and branches e^1–e^4 on the same also enter into the passages already mentioned. All these branches are provided with valves, actuated by the levers b^1–b^4, by means of which, the gas can either be admitted through the passages a^1–a^4 into the top of the oven, or through the branches E^1–E^4 into the middle of the ovens, or the gas can be shut off altogether. When the ovens are filled with ware to be burnt, tubes F^1–F^4, with perforations, are placed in them, in such a position that the gas, when entering the ovens through the pipes E^1–E^4, passes into these tubes, and is thus more equally distributed. Each of the ovens is also provided with an aperture G^1–G^4 at the bottom, connecting it, by means of a branch, with the flue H conducting to the chimney-shaft; each of the openings can be closed by dampers g^1–g^4. A large opening I^1–I^4 is provided at the top of each oven, for the purpose of filling and emptying it; each of these is temporarily bricked up when the oven is at work, but the one being open where the oven is being charged, admits air to assist combustion of gas in the oven that is being fired. If ware in A^1 is being fired, and A^2 has been recently filled, and is being heated preparatory to firing, and A^3 is being emptied and filled afresh, and A^4 has been fired and is cooling, then the action throughout is as follows. All the passages from the gas-generator to the ovens are closed, except e^1; the damper will be placed in passage a^2, and all communications with the flue H leading to the chimney will be closed except G^2; gas enters at the top of A^1 through a^4; at the same time air enters through the open oven A^3, passes through A^4, and becomes considerably heated; then passing through the passage X to the oven A^1, it mixes with the gas, and causes combustion. The products of combustion pass through a^1 to the top of oven A^2, thence through opening G into flue H conducting to the chimney. Each oven is charged, fired, and cooled in rotation. To facilitate the circulation of the heat, the wares or saggers are placed upon fire-clay blocks f, separated by suitable spaces.

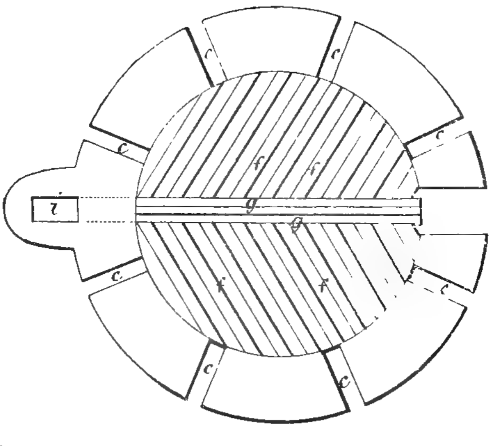
1124.



1125.

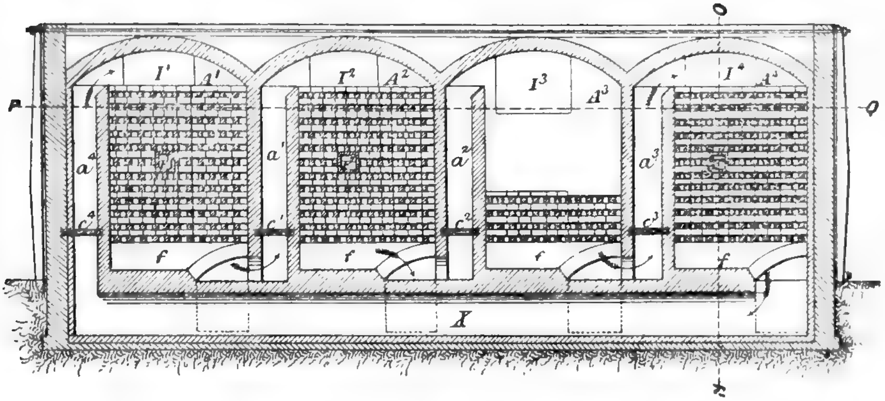


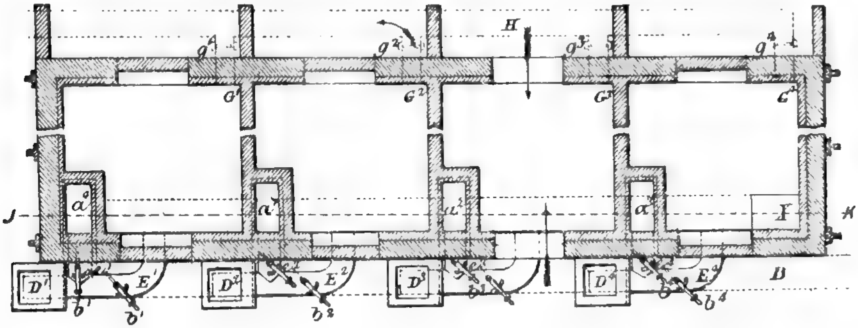
1126.



Continuous firing may be attained by causing the base of an oven to pass through fixed zones, in which the ware on the base of the oven is successively warmed, fired, and cooled. For this purpose, the oven is annular in form, and is heated by gas on the regenerative principle. Fig. 1130 is a vertical section, and Fig. 1131 a plan, of the annular oven. In Fig. 1130, T$_2$ is the annular floor or table, having a refractory facing, and being mounted on wheels t, which run on circular rails. On the under side of the table T, is a rack, gearing with a wheel on a shaft W, by turning which, the table is caused to revolve in the direction of the arrow (Fig. 1131). The wheels and axles of the table are protected from excessive heat by flanges attached to the sides of the table, and dipping into troughs of sand *s*. The annular chamber in which the table revolves is divided into four zones, namely, one for introducing or removing the ware, one for warming, one for burning, and one for cooling the ware before removal. The warming and cooling zones are interchangeable by means of two sets of apertures *p*, through either of which the gas and air can be introduced at will. If the gas and air enter by the apertures on the right, the flame sweeps through the heating zone X, and the products of combustion escape through the apertures on the left, and heat the regenerator with which they are connected. When the left regenerator is heated, and the right regenerator connected with the apertures on the right is cooled, the gas is introduced by the apertures on the left, and the products of combustion pass into the right regenerator. Whilst the flame passes from right to left in the zone X, the adjacent zone is heated by opening the flue Z, and drawing part of the flame in that direction, the adjacent zone being in this way converted into a warming zone; whereas when the flame passes in an opposite direc-

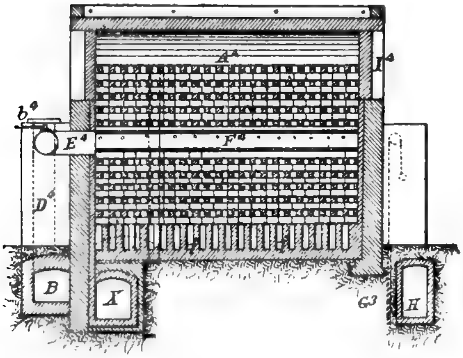
1127.



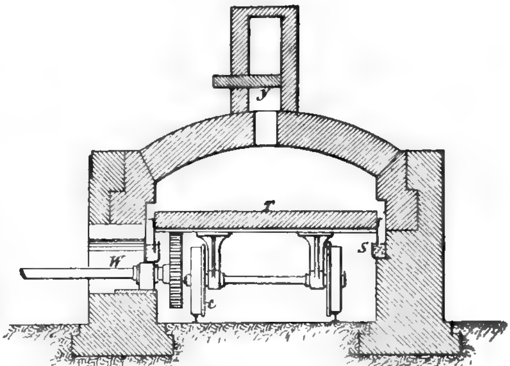


1128.

1129.



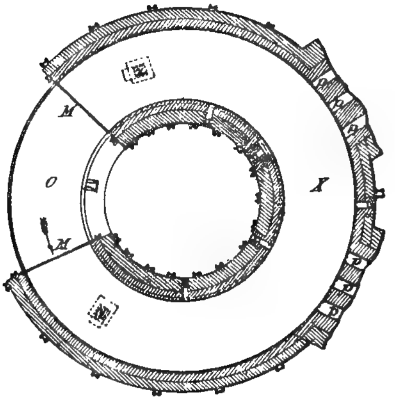
1130.



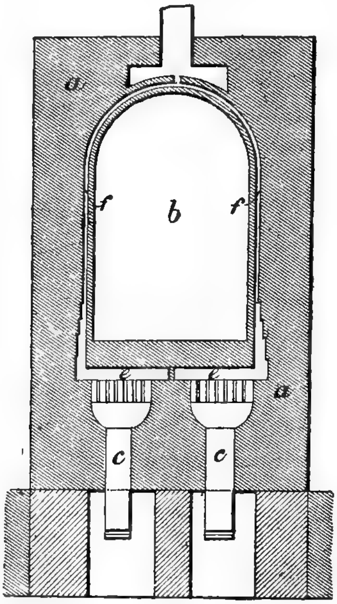
tion, and the flue Y is opened, the zone about Y is converted into the warming zone, and the zone about Z into the cooling zone. The warming and cooling zones are separated from the cold zone O by means of sliding valves M. Ware to be burnt is placed upon the part of the table O, the valves M are raised, and the table conveys the ware away from O. As the table is caused gradually to revolve, fresh wares are introduced, and burnt wares are removed at O. At each movement of the table, both the valves M require to be raised.

Closed Kilns or Muffles.—Biscuit-ware is very commonly printed with a colour mixed with a medium of a dense oily nature. This oil must be removed from the ware before the liquid glaze can be evenly spread upon its surface. The removal is effected by placing the ware in a closed chamber or muffle, beneath and around which, heat is directed by flues suitably disposed. This process is known technically as "hardening on," and the kiln used for this purpose as a "hardening-on kiln." A smaller muffle and kiln constructed on the same principle is used for fixing enamel, painting, gilding, silvering, and other forms of applied decoration to the surface of a glazed ware. The wares in either case are placed in the muffles without saggers or other protection, the fronts of the muffles, which are removable, are replaced, and all openings are luted with fire-clay, except such as are necessary for observing the course of the fire.

1131.



1132.



The manager of the Royal Worcester China-works has patented an arrangement for heating a small muffle by means of the ordinary town gas supply. A series of tubes *c* (Fig. 1132) is connected with the main, and terminates in groups of burners; the heat from each group is received into a separate compartment *e*, formed under the bed of the muffle *b*, *a* being the outer wall of the kiln. The heat from the separate compartments *e* is conducted by separate flues, passing in various directions about the muffle, into a common chimney above.

Fig. 1133 shows two or more kilns containing muffles connected with a central chimney-stalk: A is a muffle built of overlapped tiles; B, the kiln in which the muffle rests, showing the ports for directing the flame and heat from the fire-place beneath to play upon various parts of the muffle; C D, auxiliary flues; E, the main flue passing into the central shaft H; F Y, dampers; I, the entrance to the shaft for the stokers, as the fire-places are charged from within the shaft.

Although it is impossible to divide pottery into accurately distinct species, it will be convenient to classify the different kinds of ware in the following manner:—

I. Wares rendered coherent by the removal of the water mechanically combined—Sun-baked wares.

II. Wares hardened and rendered anhydrous by artificial heat, but the porosity of which is unaffected, owing to the infusibility of the ingredients—Crucibles, Saggers.

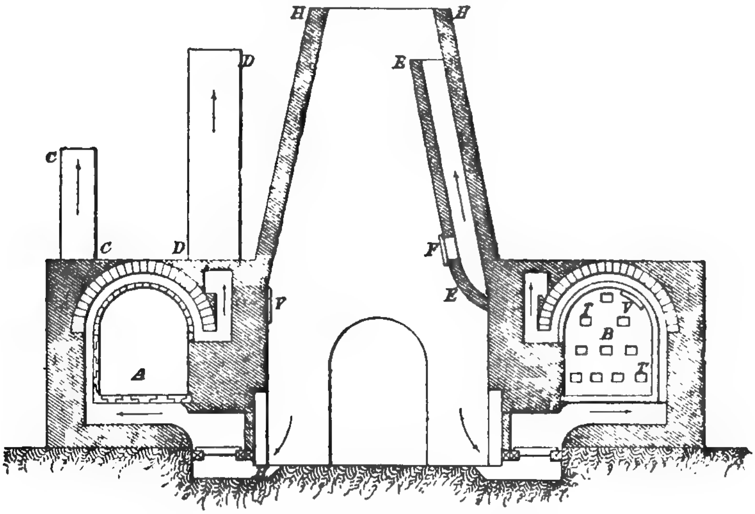
III. Wares fired at a comparatively low temperature, and porous in texture—Bricks, Majolica, Terra-cotta, Drain-pipes.

IV. Wares fired at a high temperature, and dense in texture, but perfectly opaque—Stone-ware, Earthenware.

V. Wares rendered translucent by the fusion of an incorporated felspathic glass—English china, Parian ware, true Porcelain.

Fire-ware.—In selecting clays for the manufacture of fire-ware, particular attention must be paid both to their chemical nature and to their physical aggregation. Fire-wares are required mainly for three purposes:—(1) To withstand great alternations of temperature, as in the cases of saggers; (2) to resist intense heat, without shrinkage or fusion, and, at the same time, to retain heat with as little loss as possible, as in the case of furnace-bricks; (3) to resist an intense external heat, accompanied by the internal corrosion of metals or other substances in a state of fusion, as in the case of crucibles. The refractoriness of a fire-clay may be estimated by the result of an analysis. If the proportion of foreign matter, that is to say of the alkaline, calcic, magnesic, and ferric oxides, exceed 4½ per cent., the clay is unsuitable for furnace-bricks or crucibles. No faith must be placed in the colour of a fire-clay, as the appearance of whiteness may be due to an excess of calcic oxide. The relative shrinkage of a sample of fire-clay, whether by withdrawal of moisture or by fusion, is a point demanding particular consideration in the selection of clay for the manufacture of furnace-bricks and crucibles; it is best determined by making a brick of the clay under examination, breaking it in half, and burning one half whilst retaining the other for comparison. If the burnt and unburnt halves fit together exactly, the sample may be pronounced satisfactory. The liability to corrosion is best determined by making small experimental crucibles of the clay, and fusing in them such substances as borax and plumbic oxide. If the corrosion in a given time be excessive, the clay must be condemned as unfit for metallurgical purposes. The importance of physical aggregation rests upon the fact that a coarse, porous, brittle ware withstands changes of temperature better than a dense one; whereas a smooth, dense ware is better fitted to withstand corrosion, and to retain heat. A clay is rendered naturally porous by the presence of an excess of sand; the same result, however, may be attained or increased artificially by coarse grinding, and by the addition of the coarse powder of burnt, broken, fire-clay ware, or of a foreign refractory or infusible substance, such as graphite.

1133.



Saggers.—Saggers are not required to withstand a very intense temperature for prolonged periods, nor the corrosive action of fused material; the economy, however, of a manufactory depends in some measure upon the possibility of using them several times, and upon their withstanding, without breaking, repeated heating, cooling, and reheating. As the saggers in a kiln are piled in columns, the result of the breakage of one sagger during firing may be disastrous. Considerable care is therefore expended upon the selection and preparation of fire-clays for sagger-making, but their purity is inferior to the fire-clay used for crucibles and fire-bricks. The mixture generally employed consists of inferior fire-clays, together with a proportion of the powder of broken burnt saggers.

The fire-clays, after arriving at the works, are exposed in heaps to "weather" for as long a time as possible (see Clay—Fire-clay, p. 639). When required for use, the clay and broken saggers are coarsely ground under iron wheels working upon an iron revolving base. The mixture is then thrown through a grating into a circular underground tank containing water, and is crushed and mixed with the water by the revolution of a horizontal-bladed wheel. When the liquid mixture has been tested, and found to be sufficiently dense, it is run through a long imperceptibly-sloping trough, in order that the coarser grit and particles of iron may be precipitated by gravitation, and be intercepted by depressions arranged in the trough at regular intervals. From the trough, the mixture passes into a steam-jacketed iron tank, in which it is reduced by evaporation to a suitable consistency for manipulation. The surplus heat from the tank is utilized in the drying-rooms.

The plastic clay is removed from the evaporating-tank, and, in order to ensure a close-grained and tenacious mass, is either repeatedly rolled and beaten by manual labour, or passed through a mill ("pug-mill"), in which it is mixed, pressed, and kneaded by the revolution of a cylinder armed with splayed knives, and from which it is finally driven in a continuous compact stream of the exact form of the orifice from which it issues. The stream of clay is cut into blocks, which are carried wherever they are needed for manipulation.

Saggers are manufactured in different ways, according to the different purposes for which they are intended. They may be moulded by hand on large potters' wheels, or whirling-tables, in the same manner as deep hollow ware is formed, or the bases and sides may be formed separately. The bases are formed by beating the plastic clay into iron rings of the same shape, but of larger circumference than that of the saggers of which they are to form part.

The sides of small saggers may be made from lengths cut from a cylinder issuing from the annular opening of an expressing-machine (compare Stone-ware), and may be cemented by liquid slip on to bases formed as described. The sides of large saggers are formed from strips of the clay mixture which have passed under a roller-press. The press consists of three parallel iron cylinders, supported so as to impend over a movable iron table. The blocks of clay are placed in shallow troughs of varying width, resting upon the iron table. The table can be moved backwards and forwards beneath the cylinders, and carries with it the troughs and their contents. The cylinders are caused to revolve by the resistance offered by the clay, which, at the same time, is evenly spread and compressed. The depth of the troughs forms a gauge for the thickness of the clay. The strips of compressed clay are now removed, and wound round wooden drums, which rest upon the sagger bases, but in such a manner as to leave a margin to which the sides can be attached. The side is attached to the base by kneading with liquid slip, and the edges are united in the same manner. The saggers thus formed are dried and baked.

Fire-bricks.—The consideration of the manufacture of fire-bricks and shaped blocks for the construction of furnaces hardly falls within the scope of this article. Suffice it to say, that the importance of non-liability to shrinkage in ware of this description rests upon the fact that the greater part, and especially the crowns and beds, of furnaces intended to resist intense and prolonged heat, are built of green or unbaked material. (See Glass, p. 1049 ; also Spons' Dictionary of Engineering, article Brick.)

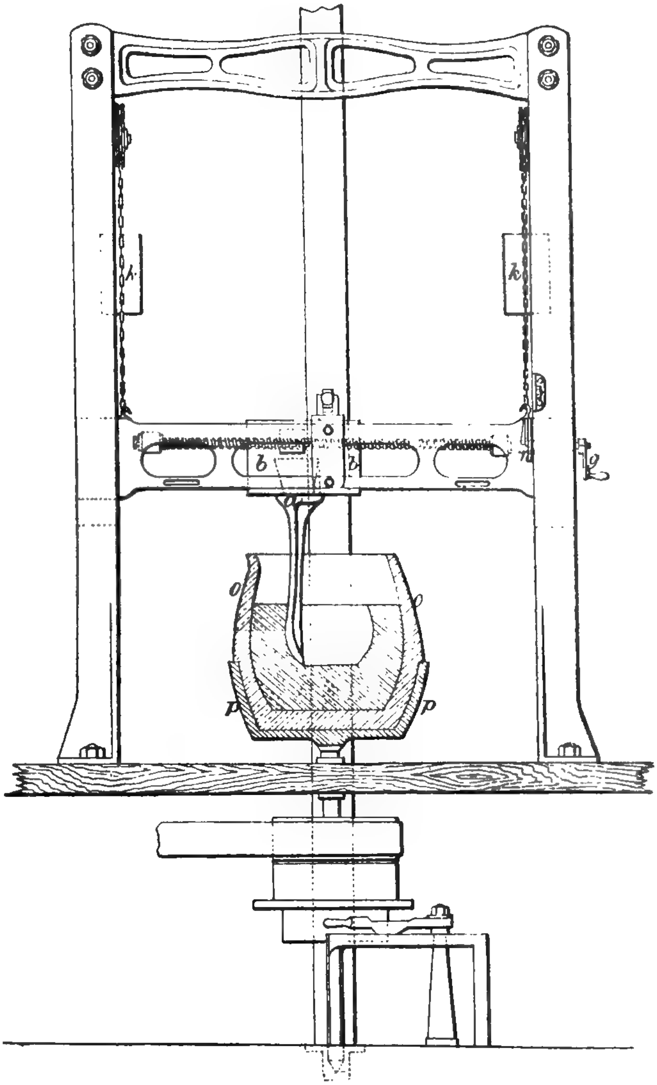
Crucibles.—Crucibles are generally formed from a mixture of almost pure fire-clay (compare analyses, p. 1559), with a greater or less proportion of fire-clay specially burned for the purpose, or of the powder of ground broken crucibles. The burnt clay is always coarser than the raw, fire-clay. Crucibles, and especially large crucibles for melting glass, are built up layer by layer by hand (see Glass, p. 1046). Crucibles of various sizes are made on the wheel, and by machinery. Machinery is largely used at the works of the Battersea Plumbago Crucible Co. The processes there employed are as follow. A graphite is selected which is as free from foreign matter as possible. The fire-clay and graphite are dried and ground separately; they are then weighed and mixed in nearly equal proportions. The mixture, incorporated with a small quantity of water, is passed through a pug-mill, and the stream of compressed and plastic material, as it issues from the mill, is cut into blocks and stored for future use.

When required for use, it is again passed through the pug-mill, and the blocks are kneaded and weighed, preparatory to working up in the machine represented in Fig. 1134, which is used in the manufacture of open crucibles for metallurgical operations. A heap of prepared clay is weighed, and inserted in a plaster mould *o*, which rests in, and is caused to revolve by, an iron cup *p*, attached to a spindle, to which, motion is communicated from beneath. A gimlet-shaped tool *a*, fitted to a block *b*, can be depressed into the clay by means of a horizontal frame, balanced by weights K. The block *b*, together with the tool *a*, can be moved horizontally in the frames by means of a handle *g* and threaded rod. The frame can be maintained in any desired position by a catch *n*. When the frame is fixed, and the mould is caused to rotate, the tool *a*, by turning the handle *g*, is moved horizontally, and spreads the clay against the wall of the mould; by this means, the form of the interior of the vessel is given by the tool, whilst that of the exterior is produced by pressure against the internal surface of the mould. By varying the forms of the tool and mould, variously shaped vessels may be produced. When the vessel has been fashioned, and the motion checked, the tool is moved into the centre of the vessel by turning the handle *g*, the frame with the tool is raised, and the mould with the vessel inside it is removed to a drying-room by means of a suitably-constructed crane. The crucibles are burnt in saggers or muffles. In order to prevent absorption of moisture and dirt during storage, they are often coated with a waterproof paint, or with an enamel which is permanently fixed by firing.

Stone-ware.—There are two very distinct species of stone-ware, the type of the one being an ordinary glazed drain-pipe, whilst the type of the other is a vase of decorated Doulton ware. The materials and treatment of both are similar, although not identical; and both types may generally be seen in course of manufacture at the same works. Stone-ware is always dense, refractory, and opaque; the finer qualities resist corrosion by acids, and extreme changes of temperature, and, in some cases, are semi-vitreous, and capable of receiving coloured decoration. The basis of all stone-ware is the grey-coloured ball-clay from Dorsetshire and Devonshire, and especially those qualities containing a considerable proportion of sand. For common ware, a mixture is made of the ground ball-clay, with the powder of burnt broken goods; for fine and decorative purposes, a superior quality of the ball-clay is mixed with sand or flint and Cornish stone. The colour of the ordinary stone-ware, after burning, is buff passing into brown; whereas that of superior stone-ware is almost white. The majority of stone-ware is glazed by the indirect reaction of the vapour of sodic chloride with the constituents of the surface of the ware. The exceptions are Bristol ware, glazed with a mixture of felspar, borax, and plumbic oxide; certain common goods, which are glazed with mixtures of the oxides or sulphides of lead and iron, or with the oxide of manganese; wares glazed over by means of a "smear" (compare Decoration); and Wedgwood's jasper ware, which is vitreous, and possesses a naturally crystalline surface.

By the term "stone-ware," salt-glazed ware is generally understood. Salt-glazed stone-ware is fired for biscuit, glaze, and decoration, when decoration is applied, at one time. All forms of decoration must be applied to the ware before burning (see Decoration).

1134.

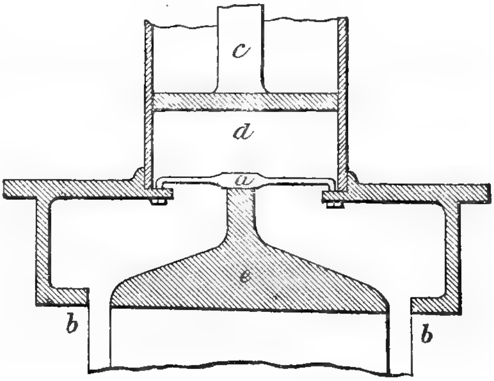


For a description of stone-ware kilns, see pp. 1565–6. The fuel generally used is coal, and the ware is exposed to the naked flame, without any protection. The difficulty of preparing colours for stone-ware decoration, which are stable enough to withstand this ordeal, can readily be understood. The heat of a stone-ware kiln is intense, and it is customary to burn terra-cotta, which is made from the same materials as stone-ware, on the roof or crown of the stone-ware kiln. Terra-cotta differs from stone-ware in its condition of solidification, which is less perfect, on account of the comparatively low temperature to which it is exposed. The unbaked stone-ware, preparatory to being exposed to the sodic chloride vapour in a salt-glaze kiln, is dipped in a mixture of sand and water. After the ware has been arranged, the fires are raised gradually. The salt (sodic chloride) is not introduced until 2½–4 days from first lighting, when the ware has nearly attained its highest temperature. Salt is thrown into the kiln with shovels at the fire-places, and through openings in the crown arranged for the purpose. The total charge of salt for an average-sized kiln is about 2 cwt. When half the charge has been thrown in, the fires are increased for a time, specimens of the ware are then examined, and if the inspection be satisfactory, the residue is added. The openings in the crown are now closed, and the ware is left to cool for 4–6 days. The injection of the salt causes dense white fumes of salt vapour tainted with hydrochloric acid to issue from the cone of the kiln. At Doulton's works, the fumes from all the kilns are gathered into and discharged from a chimney some 300 ft. high. By this means, all real nuisance is obviated.

The theory of salt-glazing rests upon the decomposition of salt vapour by water vapour. As the salt is volatilized, it unites with the water vapour arising from the combustion of the fuel, to form hydrochloric acid and sodic hydrate; the latter unites with the free silica in and on the surface of the ware, to form sodic silicate. The sodic silicate renders fusible a small proportion of the aluminic silicate of the body of the ware, and unites with it to produce a glass or glaze built up of the sodic and aluminic silicates. This glaze answers in composition to the glaze of Chinese and Sèvres porcelain; but it is more evenly spread, and, if possible, more thoroughly incorporated. If ferric oxide be present in the body of the ware, or if, as sometimes happens, red-lead be introduced into the kiln with the salt, ferric and plumbic silicates will respectively be formed, and will contribute to the fusibility of the glaze. A pure clay body is less readily glazed by the salt-glaze process than one containing free silica, alkalies, and ferric oxide; by the latter, if an appreciable quantity be present, the glaze will be tinted buff or brown. The scorched appearance, which may sometimes be observed on pieces of stone-ware, is due to the reaction of the salt vapour being in some way accidentally interrupted.

Manufacture of Common Stone-ware by "Expression."— Drain-pipes, roofing-tiles, perforated bricks, and similar articles, are produced by mechanical pressure. The processes are as follow. The ball-clay and burnt broken ware are separately ground under pairs of iron edge-runners. A scraper follows the runners, and drags the ground clay over an iron grating, through which the fine powder falls, the coarser particles being thrown back for regrinding. From the receptacle beneath the grating, the ground ball-clay is removed, and carried upwards in open pockets attached to an endless band moved by machinery. As the pockets turn to descend, the powder is thrown into a blunger, where it is incorporated with a small quantity of water, and a measured proportion of the ground burnt clay. The mixture is removed from the blunger, and supplied to a vertical pug-mill, by the knives of which, it is compressed, and forced downwards and outwards. The stream of prepared mixture is cut into blocks, and the blocks are carried by an endless band, fitted with shelves, to an upper floor, where they are stored for use. The expressing-machine occupies two floors, and the feeder is upon the upper floor, to which the blocks of clay are carried direct from the pug-mill. The principle of an expressing-machine in its simplest form is illustrated by Fig. 1135. The plunger and part of the cylinder in which it moves are represented. The clay can be introduced into the cylinder immediately below the plunger, and the door by which it is inserted can be securely closed; as the plunger, which moves airtight in the cylinder, is caused to descend, it compels the clay beneath it to assume the form of any resisting environment; and, if there be an opening, to assume its outline, and to stream through it so that a section of any part of the stream has the same outline as that of the aperture through which it has passed. If the aperture be a simple slit, the clay issues as a ribbon. Roofing-tiles are made by cutting into lengths a ribbon produced as described, placing the separate lengths whilst still plastic upon plaster moulds of the form which the tiles are required to possess, and baking them when dry. If the aperture be annular, the clay issues from it as a continuous hollow pipe. In order to form a perfect annular opening, it is necessary to support a core in the centre of the main opening, and in such a way that the supports shall not interfere with the continuity of the resultant pipe. The core *e* is attached to the base of the cylinder by the supports *a*. The cylinder is enlarged below the attachment of the supports, in

1135.



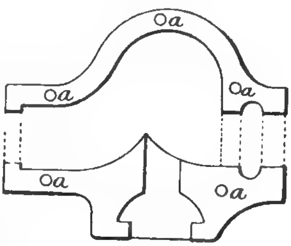
order to allow the reconsolidation of the clay after having been cut by the supports, and before issuing from the annular space *b*. As the pipe issues from *b*, it is cut by wire into any required lengths.

Additional apparatus is necessary to form pipes with flanges or sockets attached. A movable iron mould or core of the shape of the inside of the socket is placed by hand in contact with the base of the core *e*, so that the pipe, if the pressure be continuous, must be forced over it, and be enlarged in its passage. This internal mould is supported in position by a rim attached to the base of an iron collar, formed of two jointed halves. The internal form of the collar is the same as that which the exterior of the socket is intended to receive, and its internal surface forms a continuation of the outer edge of the annular aperture *b*. When the two halves of the collar are united, there remains no aperture for the escape of the clay, and it is therefore forced to adapt itself to the internal form of the socket-mould. Conical pin-holes are, however, provided in the collar, to permit the escape of imprisoned air, and the consequent perfect adaptation of the clay to the mould. The exudation of clay through these pin-holes marks the time when the socket has been formed, and when the collar and internal mould must be removed, in order to allow the simple pipe to follow after the socket. Wooden "forms" are used to rectify any inaccuracies in the shape of the sockets or barrels of the pipes. Expression may, in a similar manner, be applied to the production of a great variety of wares, as, for instance, in the manufacture of perforated and damp-course bricks.

Stone-ware jars, bottles, and jugs are fashioned on the wheel, which, in large manufactories, is generally driven by power. The more delicate specimens of decorative stone-ware, which are known as Lambeth ware, are formed on the hand-driven wheel. For the different decorative processes applied to stone-ware, see that section.

Tall chimney-pots are at times made up of as many as three lengths, fashioned separately on the wheel, and built up one upon the other. V-shaped pipes are made by the union of two separately formed pipes. Siphon-pipes are made by moulding. Fig. 1136 represents the half of a plaster mould for this purpose: *a* are the studs or depressions by which the two halves of the mould are fastened together. "Bats" or thin sheets of clay are spread carefully by hand over the entire surface of the two half-moulds. The two parts of the mould are then united, and the division between the two halves of the pipe is carefully closed by the insertion of strips of plastic clay. Large filters are similarly fashioned; but in this case, external decoration is produced at the same time as the actual form of the ware.

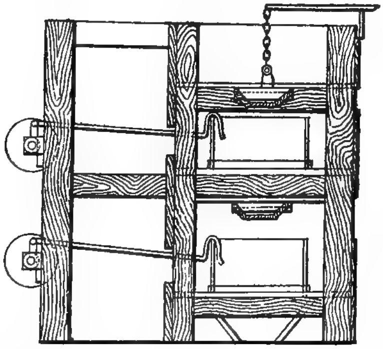
1136.



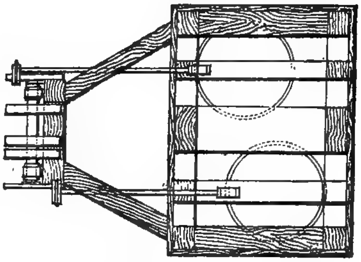
Earthen-ware.—Earthen-ware possesses a dense, opaque, and generally white body, with a rough fracture. The whiteness, opacity, and stability of earthen-ware are in a great measure due to the presence of a considerable proportion of calcined flint. There are many species of earthen-ware, distinguished by their fracture, or by the tints of their body or glaze. The ingredients of which earthen-ware is composed are ball-clay, kaolin, flint, and Cornish stone; and the glaze with which earthen-ware is generally coated is soft, containing plumbic oxide and borax. The blue or ball-clay and the kaolin or China clay, after their arrival at the works, are exposed to the action of the weather. It is convenient if the clay-banks can be so placed as to be above or on the same level with the sheds in which the clays are "blunged," that is broken up with water. When the clays are ripe, a certain quantity of each is moved to the blunging-shed, and subjected to the process of blunging. The clays are thrown into tanks containing pure water, and are mixed with the water, either by the mechanical action of blades attached to a horizontally-moving wheel driven by steam-power (see p. 1559), or by a laborious process of manual stirring with a wooden instrument resembling a large paddle. Separate tanks are provided for blunging the ball-clay, the kaolin, and scraps and shavings of broken unburnt ware. The density of the contents of each blunger is tested by weighing one pint of each in a standard pint measure. If the liquid in either case be too dense, more water is added; if not dense enough, the proportion of clay is increased. The weight of the standard mixture of ball-clay is 24 oz. a pint, that of kaolin being 26 oz. If the density be correct, each liquid mixture, or slip, is run separately by gravitation, the blungers being purposely erected on an elevation, either through a series of sieves, or into a horizontal, rotatory, cylindrical sifter. Figs. 1137, 1138 show an arrangement of sieves. Fig. 1137 is a vertical, and Fig. 1138 is a horizontal section of the apparatus. A series of sieves, with "lawns" of increasing fineness (two only are shown in the figure), are placed one above another, in such a way that the material can pass from one into the next. A backward and forward motion is communicated to each sieve by a hooked rod, loosely attached to a point on the circumference of a wheel which revolves in a vertical plane. The bases of the sieves rest upon narrow slabs of plate-glass, by which means, friction is reduced.

The actual form of the rotatory sifter is octagonal rather than cylindrical, and it receives a shaking motion in addition to rotation, through a strap driven by power. The sifting medium of the sieves and of the cylindrical sifting-machines is silk lawn, brass gauze having been tried without success. It is customary for potters to contract with the makers of the silk sifting-machines to keep their sieves in working order, as, owing to the great delicacy of the material, they are constantly liable to damage. The sediment retained by the sieves or sifting-cylinders is emptied from time to time into convenient receptacles, and returned to be reblunged. After sifting, the clay slips are run separately into the mixing-tank, in which, a measure fixed to one side indicates in inches the quantity of each material received, the density of each liquid having already been determined by weight. The relative quantities of the clays, as of the other substances, vary according to the nature of the ware it is intended to produce. The mixing-tank is generally of stone, measuring about 6 ft. sq. The flints, after calcination and crushing (see p. 1561), and the Cornish stone, after crushing, are ground separately with water. In the mills used for this purpose, the necessary friction is obtained between two surfaces of differently-grained chert. A cast-iron bed is evenly paved with blocks of carefully selected stone, but in such a manner that the circumference of the bed shall be at a higher level than the centre; the bed is surrounded by sides of wrought-iron, and the centre is pierced by an opening, in which, revolves an iron vertical shaft, driven by gearing from below. To the shaft, are attached four curved projecting arms, each provided with vertical, wooden, iron-tipped bars, which reach almost to the bottom of the pan, and propel heavy masses or "runners" of the chert rock.

1137.



1838.



Pure water is first run into the pans formed by the beds and sides of the mills, and the materials to be ground are then added. As the "runners" are forced round and round, the flint or Cornish stone is respectively ground to an impalpable powder, and worked with the water so as to form a compound of a thick creamy consistency. The mixture in either case is allowed to settle for a short time, and is then drawn off through plugs at different heights in the sides of the pans. From the top plug, water is drawn off; from the second, the slip or mixture which is to be used; and from the bottom plug, a sediment which requires to be reground. The flint and Cornish stone slips are thence conducted into circular tanks, where water is gradually added, and where the material is mixed with the water by the revolution of an agitator or spindle with arms and paddles, until such time as the mixtures respectively attain a standard density. The density is determined, as in the case of the clays, by weighing a fixed quantity. The standard weight of a pint of flint slip is 32 oz., and that of Cornish stone is generally the same. The creamy liquids are run through pipes into store-tanks in the clay blunging-shed, the inlet to the pipes being slightly above the level of the bottom of the agitating-tanks, in order that any coarse sediment still present may be retained for regrinding. The flint and Cornish stone slips are now under the same roof with the clay-blungers and mixing-tank, and are introduced into the mixing-tank, the quantity of each being regulated by the measure attached to the side of the tank. At this point, also, any colouring mixture that may be required is introduced. In the mixing-tank, the clay slips, together with the flint, Cornish stone, and any colour that may be present, are thoroughly mixed by agitation, either by hand or by power. The mixture is then passed through three sifting-machines or three sets of sieves, each sifting-machine or set of sieves being covered with lawn of increasing fineness. The coarsest lawn contains 50 threads in an in.; the finest, 120 threads. After mechanical sifting, the mixture is subjected to magnetic or electrical sifting, in order that it may be purified from minute particles of iron. For this purpose, the trough through which the fluid is conducted is furnished with a series of horse-shoe or electro-magnets, and the fluid passes through their field of action. After this double process of purification, the liquid mixture or slip reaches an underground store-tank or "ark," whence it is raised by pumps to be partially solidified by pressure and filtration.

The following table shows the number of inches of each liquid material of standard density required to make up 100 in. of the different earthen-ware mixtures in a liquid condition.

Ingredients.	Weight per Pint.	Earthen-ware proper.					Cream Colour.		Granite	Iron-stone.	Fritt for Glaze of D.		Glaze for D.	
		A	B	C	D	E								
	oz.										Ingredients.		Ingredients.	
Ball-clay ..	24	32	35	36	40	25	48	65	10	24	Borax	30	Fritt	50
Shavings and waste of unburnt ware ..	..	..	..	..	..	25	..	..	..	..	Kaolin	5	Cornish stone ..	25
											Calcic carbonate	20	Plumbic carbonate	25
											Cornish stone ..	30		——
Kaolin	26	36	45	32	32	25	24	17½	40	24	Flint	15		100
Flint	32	22	15	20	20	12½	16	13¾	28	16		——	or equivalent of oxide.	
Cornish stone	31½–32	10	5	12	8	12½	12	3¾	22	36		100		
		100	100	100	100	100	100	100	100	100				

The table serves rather as an illustration of the attributes of the different materials than as a basis for manufacture. Ball-clay (see p. 1558) supplies plasticity, but acquires a slightly yellow tint when fired, which is especially noticeable when the commonest qualities of the clay are used. Kaolin contributes plasticity, whiteness, and infusibility; flint contributes whiteness, stability, and an earthy fracture; and Cornish stone acts as a flux, and produces vitreosity. Whenever any one of these ingredients is in excess, the quality or qualities which it possesses show themselves in the resultant ware. Thus the mixture B will produce as white but a less vitreous ware than A, for although the proportion of ball-clay in the former is greater than in the latter, the proportion of the whitening ingredients, kaolin and flint, in B is greater than that possessed by A. In E, the proportions of ball-clay, kaolin, and flint are reduced, as deficiency in whiteness and plasticity is supplied by the addition of 25 per cent. of the shavings and waste of unburnt ware. The colour of the cream-colour ware is due to large proportion of ball-clay, which, in the samples given, amounts to as much as 48 and 65 per cent. "Granite" is vitreous, owing to a large proportion of Cornish stone; but part of this effect is balanced by the presence of an excess of kaolin, which renders the ware white, and somewhat refractory. "Iron-stone" is vitreous, owing to a comparative deficiency of clay, and a great excess of Cornish stone.

1139.

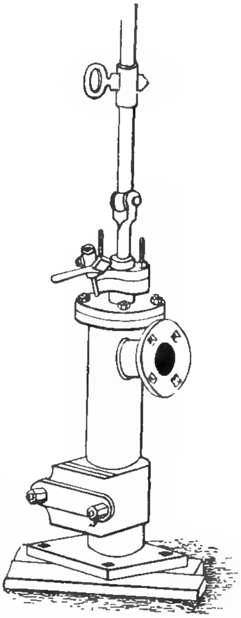
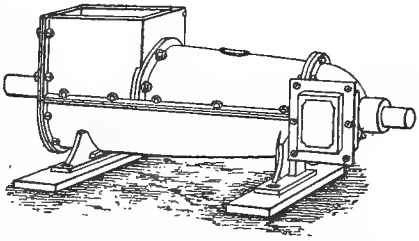


Fig. 1139 represents an ordinary pump used for raising the liquid clay mixture from lower to higher levels, whilst it is undergoing the different processes of refinement. The pump employed for forcing the slip from the store-tank into the press is of special construction, and of considerably greater power. The press is made up of a series of large, oblong, wooden, shallow trays or frames, usually 24 in number, which are grooved or ribbed on both faces, and, when placed vertically side by side, leave intermediate spaces of about ¾ in. In each of these spaces, is laid a piece of strong calico, of rather more than double the size of one of the frames; and the calico is so folded as to form, in the space between the frames, a bag, into the upper side of which, a small brass pipe is fixed, which can be adjusted to a main supply-pipe running above the frames and connected with the slip-pump. When the frames, with the bags between them, have been set together, and tightened up by means of screw-bolts, and when the small distributing-pipes have been connected with the supply-pipe, and the pump has been set in motion, the slip is drawn from the store-tank, and forced successively into the 24 bags. As more and more of the slip is driven in, the pressure in the bags is increased, which is resisted by the strength of the calico, the wooden framework, and the tie-bolts. The pressure causes the water to separate from the clay, and filter through the calico, and, passing through openings in the wooden framework, to run in a channel beneath the press into a tank placed for its reception, whence it is pumped for use in the "blungers" or elsewhere. When the water ceases to flow from the bags, the pump is checked, the main supply-pipe is disconnected from the distributing-pipes, the tie-bolts are loosened, and the frames are separated. When the calico between the frames is unfolded, a thin sheet of plastic clay, corrugated by the ridges in the wooden frames, is discovered. In order to prevent loss during the action of the pump, through the bursting of any one of the bags, each of the small distributing-pipes is furnished with a stop-valve, by which its connection with the supply-pipe can be closed, without interfering with the process of filtration in the remainder of the bags.

The clay or clay mixture is now practically pure, and requires only to be freed from the air which is still retained in its pores, and to be rendered close-grained and tenacious. This result is obtained partly by a mechanical and partly by a manual process. The mechanical process is performed by the "pug-mill," Fig. 1140. It consists externally of a conical, cast-iron, horizontal case, with a hopper on the upper part of the large end of the cone, and with a comparatively small square or octagonal orifice on one side of the small end. A shaft passes through the length of the cone, having iron splayed blades fixed spirally round it. The shaft is driven by power, and the clay, which is thrown into the hopper, is mangled and driven forwards by the revolving blades. The shape of the mill causes the clay to be more and more compressed, until it issues from the orifice in a compact stream. The stream of clay is cut into blocks by a tightened wire, and the blocks are conveyed to the different workshops. The manual process of compression is only necessary for clay which is intended for the finest work. It consists in placing the block of clay, as it comes from the pug-mill, on a bed of plaster, and repeatedly cutting it horizontally with a wire, and hurling one half upon the other with all the power the operator can muster.

1140.



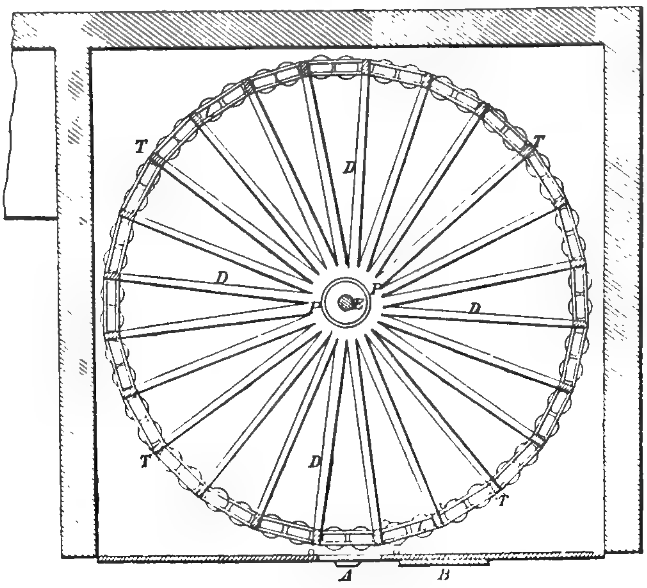
Processes of Manipulation.—*Throwing.*—The process of "throwing" is the application of the principle of "turning" to a plastic material, the turner's tools being replaced by the more delicate fingers of the "thrower." The main apparatus, or "wheel," consists of a horizontal disc, rigidly fixed on the top of a vertical spindle, to which, rotatory motion can be communicated. In addition to the wheel, the thrower has a balance, in which the pattern to be reproduced is counterpoised by the lump of clay from which the reproduction is to be made. The pattern generally only bears a very slight resemblance to the finished article, as ware is now seldom finished on the wheel, but subsequently passes through the turner's hands, by whom it is sometimes reduced to one-half its original substance. As a rule, except in the case of fine stone-ware, the "thrower" gives the inside form only, and leaves the outside to be fashioned by the "turner."

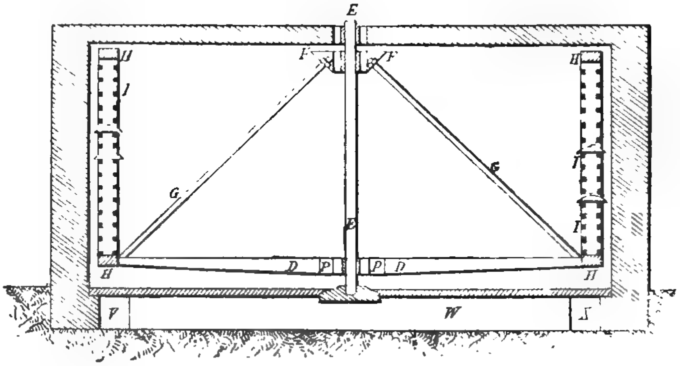
A box to sit upon, a basin full of water, a movable gauge, with a horizontally-revolving needle or pointer conveniently placed for comparison with ware during manipulation, together with a few pieces of thin horn or wood, complete a thrower's equipment. The weighed mass of clay is dipped into the basin of water, and thrown upon the disc, which is sometimes made of copper, sometimes of wood. The disc revolves, and the clay, hollowed by the pressure of the thrower's fingers, rises and falls, contracts and expands, according to the velocity of the wheel and the touch of the thrower. When the vessel attains the height indicated by his gauge, and the requisite form, and has been smoothed from ridges within and without by the pressure of yielding fragments of horn or wood, the wheel is checked, and the vessel, severed from the disc by a fine tightly-drawn wire, is removed by an assistant to the drying-room, where it is partially dried previous to being finished by the turner.

Turning.—The turner's lathe in many respects resembles that employed for turning wood or metal. The vessel to be turned is fixed by a small rim of moist clay upon a wooden block, fitting the interior of the vessel, and projecting from a horizontal spindle, to which, motion can be communicated. The tools employed are thin slips of metal or horn, and a polisher consisting of a piece of Parian ware; sometimes a metallic profile is used, and pressed against the revolving vessel. The turner reduces the superfluous substance of the vessel, and finishes the exterior, the bottom, and the rim; he also, when necessary, polishes the surface. After turning, the ware is replaced in the drying-room, previous to being fitted with handles, spouts, or applied decoration. Before removal, however, the internal form of small open ware, as, for instance, cups, is corrected by pressure upon a wooden cone.

Drying.—The drying-room, to which reference has been made, was originally a 10-ft. brick chamber, with a central stove, and shelves upon the walls for the reception of ware. For the placing and removal of ware, boys had to be repeatedly entering this chamber, a practice which was both laborious and unhealthy. Many contrivances have been devised to do away with the necessity of entering the drying-room, by causing a movable frame to carry the ware from the entrance of the room through the heated atmosphere, and back to the entrance for removal. The best known drying-apparatus is that invented by Colin Minton Campbell, and represented in Figs. 1141, 1142. The heat is supplied to the drying-chamber by the waste or exhaust steam from a steam-engine through the flues V, W, and X. In the centre of the chamber, is a vertical axis E, from which, project horizontal arms D, attached below to the collar P, and above, by the sloping rods G, to the collar F; they carry at their outer ends a circular rack H I, whose outer edge comes within a short distance of the outer wall of the drying-chamber. In this wall is an opening, covered by a sliding-door A B, through which the ware can be placed upon or removed from the rack. The rack is made with several shelves one above another, and each shelf is made of two concentric strips of wood, with space between, to facilitate the circulation of the heat. The shelves are divided into compartments, by vertical partitions running from top to bottom. The machine moves easily on its axis, and a touch of the hand will cause it to revolve, and expose one compartment after another. Fig. 1143 shows another arrangement, in which, pans supporting the ware are loosely suspended, in the same manner as scale-pans, from transverse bars fixed to the transverse circumference of a large, revolving, perpendicular wheel. The wheel is wide, and the pans hang between its two sides; the bases of the pans remain horizontal by force of gravitation during the entire revolution of the wheel.

1141.



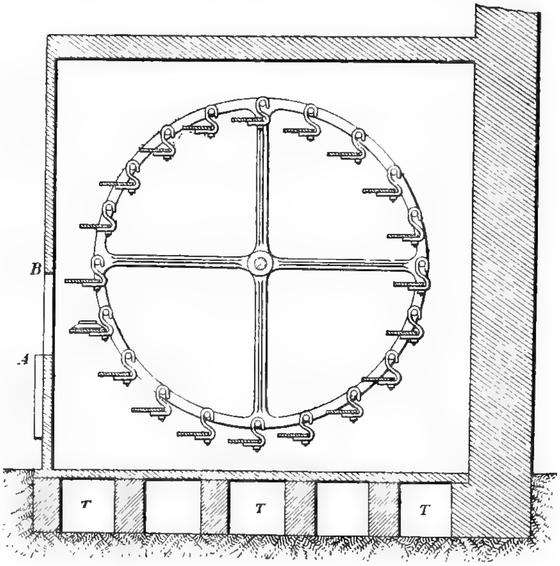


1142.

Handles.—Handles are always formed separately from the ware to which they are to be attached, and may be made in several ways. Those which have the same section throughout are cut from a long strip of clay, which has been forced through a metallic template of the requisite shape, placed at the base of a conical case, in which, works a plunger driven by a screw and fly-wheel (Fig. 1144). Ornamental decorated handles are formed by pressing the plastic clay into moulds of plaster of Paris; and light hollow handles, by the injection of a liquid clay mixture into a mould of plaster, and by the deposition of the clay upon the porous surface of the mould (compare Casting, p. 1596). Handle, spout, or whatever is applied to ware in this stage, is fixed by liquid slip, every trace of the joint being carefully removed. At this stage, also, any holes that may be required, as, for instance, in the strainers of tea-pots, are pierced. In the latter case, all the holes are pierced at one blow, by a tool with an equivalent number of points.

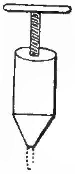
Moulds.—Reference has already been made to plaster of Paris moulds. Few, except the smallest vessels, are made by the thrower, the great majority being formed in moulds. The moulds therefore form the most valuable and, at the same time, the most cumbrous element in the potter's plant. The material of which the moulds are made is plaster of Paris, which is preferred on account of its power, when dry, of absorbing moisture from the clay in contact with it, also on account of the ease with which it can be manipulated. Any number of moulds can be made successively from one model prepared in clay or plaster of Paris, by simply pouring the plaster, rendered liquid by admixture with water, over the model, and allowing it to set. If the surface of the model be covered with a pattern in relief, the mould will have the same pattern impressed, and the clay ware will have the same pattern in relief. In this way, the raised basket-ware, fluted, and flower and leaf patterns on common ware are produced.

1143.

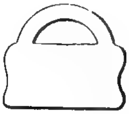


Batting.—The process of moulding or "pressing" consists first in forming thin layers or bats of clay, and then inserting and pressing them into moulds, which are generally in two pieces, to facilitate the insertion of the "bats," and the removal of the moulded ware. Bats of clay are formed by hammering out blocks of clay on a bed of plaster of Paris, with a wooden 10-lb. mallet, of the shape represented in Fig. 1145, or by machinery. The employment of machinery is desirable, as the process of hand-batting is both slow and laborious. In the batting-machine represented in Fig. 1146, the clay is pressed between two iron discs with surfaces of plaster of Paris. The upper disc rises from and falls upon the lower stationary disc by means of cranks driven by power. The thickness of the resultant "bat" can be regulated by set-screws; the clay is fed into the small hopper shown in the figure, which opens automatically, to allow the clay to fall upon the lower disc when the upper disc is at its highest point. A modified form of this machine has been introduced, in which are three stationary discs, fixed upon a revolving table, in such a manner that they are successively carried by the table under an upper disc, to which an up-and-down motion is supplied, as in the single batting-machine, already described.

1144.



1145.

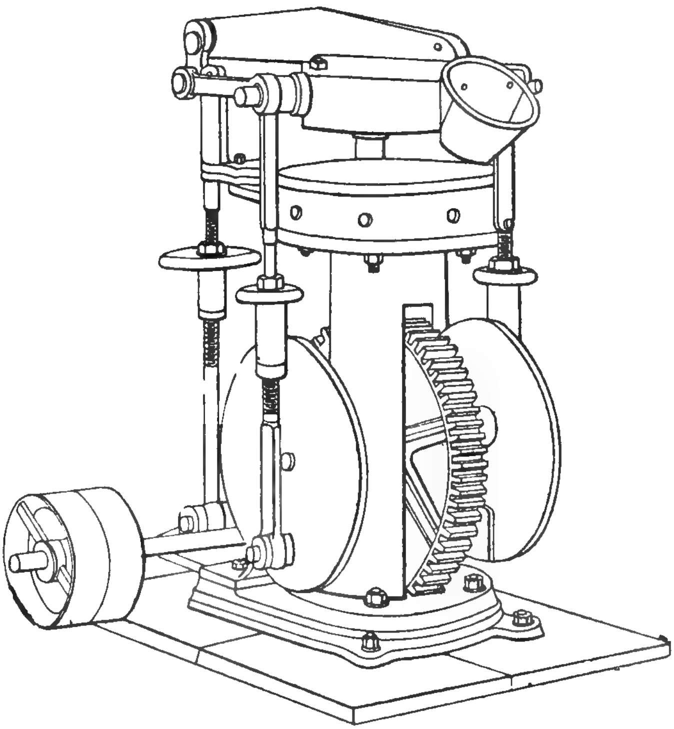


Pressing.—The simplest form of pressing is that employed in the manufacture of plates, and is known as "flat-pressing." The mould is an exact reproduction in plaster of Paris of the inside of the plate to be produced. It is placed upon a block of plaster of Paris, held by four bent wrought-iron arms attached to a vertical spindle, to which, motion is supplied either by hand connected with a large vertical wheel turned by a handle, or by the friction of an endless band driven by power. In the latter case, a pulley is fixed to the lower end of the spindle, to which the band can be transferred from another free pulley, on which the band travels when the spindle is not in use. This band is transferred by the pressure of the operator's knee upon a lever connected with the free pulley. The spindle with the iron frame and plaster head is known as a "jigger." The old process was to place upon the plaster mould a bat of clay, to press it with the hand until its internal surface assumed the form of the mould, that is the form of the inside of the plate, and then to press upon the upper surface of the clay a template or profile having the exact form of the bottom of the plate, the pressure and profile being applied whilst the spindle was in motion.

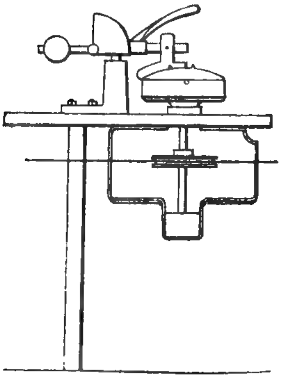
If the spindle be driven by power, the whole operation can be accomplished at once. The profile (Fig. 1147) is fixed to the end of a movable arm, carried by an upright support screwed to the bench through which the spindle works. The arm and the profile can be adjusted at any required height above the mould, and the profile can be pressed upon the clay as it revolves on the "jigger" head, by the handle shown in the figure. After the plate has been formed, it is removed with the mould to the drying-room, and another mould is substituted. Figs. 1148, 1149 show another case of a profile for shaping the inside respectively of a simple and an under-cut vessel. In each, a bat of clay is carefully placed inside a plaster mould fixed on a jigger-head. The profile A (Fig. 1148), attached to the rod B, counterpoised by the weight D, is controlled by the handle C. The jigger-head P, turning upon the spindle L, supports an apparatus for fixing the mould M.

By means of screws passing through the blocks G H, and pressing upon the rubbers I, the mould can be placed in any desired position upon the jigger-head, and eccentrically to the profile. In Fig. 1149, the profile S turns upon an axis, and can be forced into the clay, or withdrawn, as required. If the jigger be set in motion, and the handle be pressed so that the profile be driven into the clay, the vessel will have on its outside the form of the mould, and on its inside the form given by the profile. The mould is made in two pieces, so as to permit the delivery of the vessel. A machine has been introduced for applying an automatic profile to a succession of vessels carried upon a revolving table, each vessel being held in a separate mould and jigger-head. The moulds for ewers, and other vessels of similar shape, are made in two halves; bats of clay are skilfully laid in both halves, and adapted to the form by means of a sponge and scraper; the two halves of the mould are then united (see Fig. 1150) and fastened by a strap, and the complete mould is placed upon a horizontal wheel moved by hand. The seams formed by the junction of the sides of the two bats of clay in the two halves are scraped down by the workman's thumb, there being free access to the interior both from the top and bottom of the mould. The depressions thus made are filled up with rolls of plastic clay, and the internal surface is made perfectly smooth by the application of a moistened sponge. The base of the ewer is made separately on a mould fixed upon a jigger-head, and has a ring of plastic clay placed on its surface, which exactly fits into the bottom opening

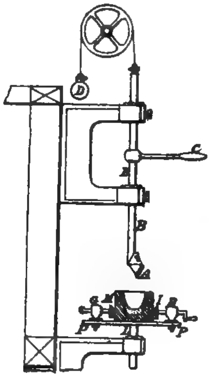
1146.



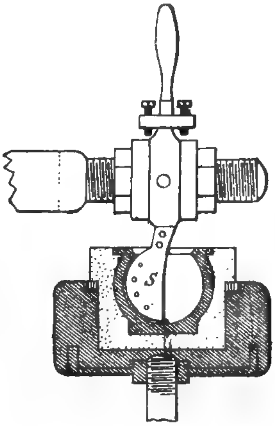
1147.



1148.

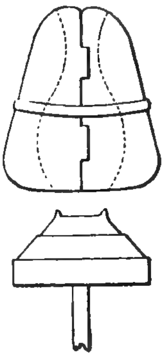


1149.

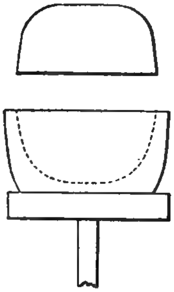


of the body of the ewer. The body of the ewer in its mould is placed upon the base, and the junction is made smooth and secure by welding the raised ridge on the base into the internal surface of the body. In forming tureens, and other deep open vessels (see Fig. 1151), whether round or oval, the bats of clay are adjusted upon a plaster block, covered with coarse flannel, of the form of the interior of the vessel to be produced; upon this block, they are inserted into the mould which gives the external form of the vessel. For oval vessels, specially-constructed jiggers and wheels are required. Their motion is adapted to this purpose by the introduction of an eccentric.

1150.



1151.

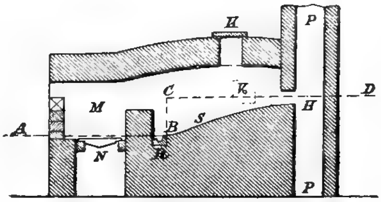


Burning.—When the goods are partially dried, they are trimmed, and when thoroughly dry, are packed in deep round or oval saggers (compare Fire-ware) to be burnt. At the bottom of each sagger, is spread a layer of calcined flint or pure sand, and the goods are packed with the greatest care. For plates, a burnt plate is placed at the bottom, and others are piled upon it. Wide-mouthed and handled wares have burnt rings of the required shape inserted in them, to prevent distortion. The saggers, thus packed, are piled one above another, the interstices being filled by rolls of clay expressed by a small screw-press, until the kiln is full (compare Kilns, p. 1563). The progress of the burning is ascertained by the periodical withdrawal of test-pieces. The firing lasts 48–50 hours. When the firing is complete, and the kiln is sufficiently cooled, the saggers are unpacked, and the ware is rubbed over with sand-paper, preparatory to printing or glazing.

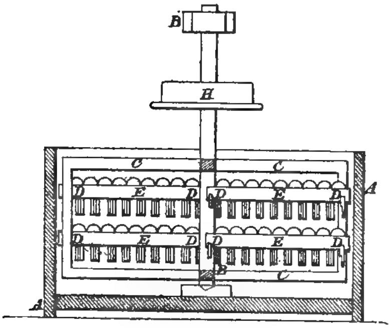
Printing.—See section on Decoration, p. 1597.

Glazing.—For the glaze, a mixture of borax, Cornish stone, calcic carbonate, flint, and kaolin, is first fused in a small reverberatory furnace, shown in section in Fig. 1152: A is the stoke-hole; M, fire-place; N, grate; K, damper; H S B, bed on which the mixture rests, having been thrown in at V; P, chimney; R, opening by which the mixture, when thoroughly fused, is run out into an iron vessel containing water. The molten mass is broken up by the cold water, and is transferred to small mills, similar to those employed for grinding flint and Cornish stone. After prolonged grinding with water, and passing through sieves of great fineness, it is purified by agitation in a blunger armed with horse-shoe magnets, Figs. 1153, 1154: B is a vertical axis driven from the pulley H; C, four arms projecting from the axis; E, bars fastened by the bolts D to the arms C, and holding the magnets, as shown. A proportion of this slip is mixed with a slip consisting of Cornish stone and plumbic carbonate, or an equivalent of plumbic oxide. Into this liquid mixture contained in convenient tanks, the wares rendered porous by burning are dipped; the mixture is kept in constant agitation, and the porosity of the ware ensures enough being taken up to produce a sufficient glaze. Considerable skill is required to dip the different forms of ware in such a manner

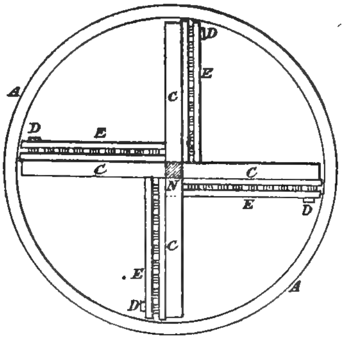
1152.



1153.



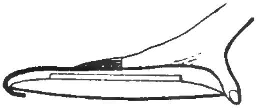
1154.



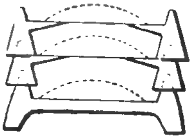
that the glaze may be equally distributed, and as little surface as possible be covered by the dipper's hand. Fig. 1155 shows an arrangement, consisting of a thimble with a hook attached, for enabling the dipper to handle with facility plates and other vessels of large diameter. When the parts that have been rubbed, or insufficiently covered with the liquid glaze, have been retouched, and the ware has been thoroughly dried, it is replaced in saggers, preparatory to the fusion of the glaze.

The ware can no longer be packed one piece upon another, as in the previous firing, for the fusion of the glaze would cause the pieces to adhere, and great damage would ensue. The ware is therefore separated by the insertion of props of refractory clay, made in such form that as small a part of the ware as possible shall be touched. Fig. 1156 shows a pile of plates, tiles, or saucers, supported and separated by hollow thimbles with pointed arms. The saggers with their contents are built up in a kiln similar to the one employed for the first firing, only somewhat smaller. The saggers, as in the previous case, are made airtight by the insertion of rolls of plastic clay. The firing lasts some 18 hours, and its progress is tested by the removal of pieces of ware, similar to that being fired, and previously dipped in the same glaze. The test-pieces are usually made on purpose, and pierced in the centre to facilitate removal.

1155.

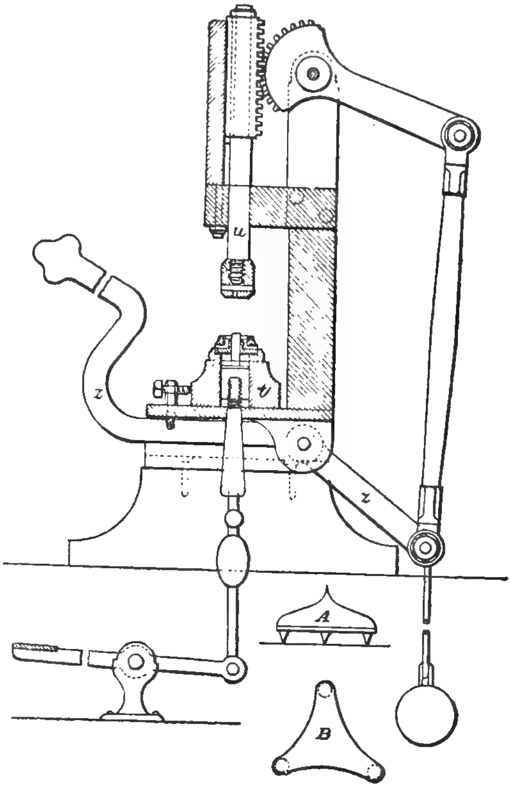


1156.



Supports.—Great ingenuity has been expended in devising and manufacturing the supports for ware undergoing the firing for glaze. Fig. 1157 represents a press for forming the supports of stilts A B. The arm and handle *z* turn rigidly upon their axis. If the handle be depressed, the vertical rod *u* is also depressed. When pressure is removed from the handle, the rod *u* is raised once more by the action of a counterpoise. When *u* is in the position shown in the figure, a strip of plastic refractory clay is placed upon the die or mould, and is forced to adapt itself to the form of the mould and plunger, by the pressure of the descending rod *u*, to which the plunger is attached. When the pressure is removed by the action of the counterpoise, the formed support may be raised from the mould by depressing the treadle. Minute apertures are pierced both in the mould and plunger, to permit the escape of imprisoned air, and consequently to ensure the sharpness of outline of the support or cockspur. Machines are now in use which produce 100 supports in one action. The moulds, as in the press already described, are in two halves, one being attached to a plunger, and the other movable. The moulds contain the number of impressions sufficient to produce the required number of supports. There are several duplicates of the lower movable half of the mould, and in this alone are the apertures for the escape of the air. The clay is supplied in a continuous stream from a miniature expressing-machine. After the clay has been inserted, and pressure applied, the lower part of the mould, which contains the supports, is removed, and another is substituted. The mould and supports are heated, and the supports are readily extracted as soon as the clay begins to contract.

1157.



After the supports are removed, the apertures in the depressions are cleared by pressing the mould upon a tool containing an equivalent number of points. The mould is then rubbed with mineral oil, and replaced under the plunger. Supports require to be burnt in the same manner as ordinary earthen-ware.

Terra-cotta and Architectural Pottery.—Terra-cotta is a term commonly applied to works having an artistic character, made of clay, and burnt, sometimes painted and glazed, but more frequently unglazed. The fabrication of fictile works known by this name was common to all the great nations of antiquity; and of late years, much progress has been made in England, France, Germany, Italy, and other countries, in reviving the manufacture of useful, ornamental, and domestic articles in terra-cotta, and in applying this material to architectural purposes.

The clay anciently used in the small vessels and ornaments is fine in texture; the larger pieces are made of rather coarser clay, combined with pulverized lava, pumice, or potsherds. They are generally much lighter than modern works of a like size. Some of the ancient pottery commonly called " Samian ware," of a beautiful coralline red, we have never perfectly imitated; there is much yet to discover relating to ancient pottery of this class. Vauquelin made analyses of fragments of Greek terra-cotta, and gives the following as some of the constituents:—Silica, 53 per cent.; alumina, 15; lime, 8; oxide of iron, &c., 24.

Between the 12th and 14th centuries, large and sumptuous edifices were erected in N. Italy of brick and terra-cotta, the latter taking the place of stone and marble for cornices, panels, string courses, and brackets. Many examples of brick buildings with terra-cotta mouldings and ornaments exist in England, having been erected mostly between the 13th and 16th centuries. Generally the use of terra-cotta died out in this country with the Tudors, and except a slight revival of moulded brickwork about the 17th and beginning of the 18th century, architectural terra-cotta was not practised until the time of George III. Towards the close of the 18th century, coeval with the great improvements made by Wedgwood in pottery, a most important advance for reviving the use of terra-cotta was established in Pedlar's Acre, Lambeth, by a lady named Coade. At these works, capitals and bases of columns, coats-of-arms, pedestals, friezes, bases, statues, balustrades, archivolts, and terminals, were made; and at the commencement of the present century, terra-cottas from Coade's works were to be met with in all the best parts of London and the provincial towns. Sculptors were employed upon models for this pottery, some of whom afterwards took to manufacturing terra-cotta on their own account. Among them was Rossi, who executed statues, capitals, and other ornaments in terra-cotta for St. Pancras church; and Bubb, who modelled and made the frieze in front of Her Majesty's Theatre, and most of the statues on the cornices, and in the tympani of pediments in Regent's Park.

Early in the present century, a manufactory was also opened at Bow, to make church-yard monuments and architectural details in terra-cotta, by Van Spangen and Powell; but it was soon closed. Some small works were opened also in various country places, but with little success. A few years prior to the International Exhibition of 1851, an inquiry sprang up for architectural details and garden ornaments, which caused the production of many excellent examples for the Exhibition. These came from many places in England, and some from Ireland and Scotland; nearly every class and variety of terra-cotta then manufactured found a place, and the specimens from France, Germany, Italy, and Switzerland were numerous.

Very little terra-cotta was painted and enamelled in the 18th century, and we are only now beginning to imitate the enamelled terra-cotta of the 14th, 15th, and 16th centuries. Since 1851, the use of terra-cotta has very largely increased in England, and it has now become a staple building-material, besides branching out in innumerable directions for ornamental and useful purposes. Considerable quantities of English terra-cotta have been exported during the past 25 years to India, Australia, New Zealand, and the United States. Within the past 10 years, the Americans have established several manufactories for this ware.

Red terra-cotta mouldings are now used in combination with red brick-work in all parts of England, and the making of moulded bricks of this class is a special business. Machinery is employed in this work, but the more ornamental and artistic pieces are pressed into plaster moulds; so also are buff and white bricks, which are coloured and enamelled for string courses and dados. White, buff, brown, red, and other clays of various tones are now used for ornamental works, and for busts, statuettes, relievi, and architectural details. The painting, gilding and enamelling of terra-cotta is rapidly improving, and thus employment of a highly artistic character is afforded to women. Busts and statuettes are to be seen in the Royal Academy Exhibitions modelled in terra-cotta clay, and fine as original works fresh from the touch of the sculptor, without the process of moulding. Architects and sculptors are paying much attention to this subject of original modelling in terra-cotta, and we may hope very soon to rival the works of Lucca della Robbia, Bernard Pallissy, and other old masters. It may be interesting here to introduce Brogniart's analysis of the clay bodies of the two great modellers just named, before giving a statement of analyses of English clays used in terra-cotta, and a list of clays especially fitted for this material. Brogniart gives the following as the elements of the wares of:—

	Lucca della Robbia.	Pallissy.
Silica	49·65	67·50
Alumina	15·50	28·51
Lime	22·40	1·52
Magnesia	0·17	..
Oxide of Iron	3·70	2·05
Loss	8·58	0·42
	100·00	100·00

TABLE OF ANALYSES OF SOME CLAYS USED FOR TERRA-COTTA AND TILES.

Constituents.	Names of Clays and Places where they are found, and Name of Analyst.											
	Blue Barrow, Cornwall, Dr. Lyon Playfair.	Bovey, Teignmouth, Mr. W. Weston.	Blue Ball. Bovey Tracey, Mr. Blake.	Blue Clay, Wareham, Mr. W. Weston.	Buff Clay, Wakerley, Dr. H. Medlock.	Oolitic Clay, Northampton, Dr. H. Medlock.	Red Clay, Watcombe, Dr. Percy.	Red Clay, Broseley, Johnson.	Red, Dunfermline.	Red, Manton, Dr. H. Medlock.	Red London Clay.	Mud of the Thames (burnt dark red), Dr. Lyon Playfair.
Silica	45·52	52·06	47·0	48·99	69·59	75·78	57·83	64·06	64·14	54·40	50·40	44·15
Alumina	40·76	29·38	48·0	32·11	20·04	15·61	20·55	20·60	13·34	18·58	24·00	11·27
Iron	..	2·37	1·5	2·34	3·37	3·54	7·75	7·16	7·57	11·75	..	5·95
Lime	2·17	0·43	..	0·43	3·16	2·12	1·68	0·12	1·90	2·48	2·70	17·02
Magnesia	traces	0·20	2·0	0·22	3·18	2·40	0 97	0·04	..	3·41	1·30	2·25
Titanic acid	..	..	..	..	..	..	..	0·62	..	..	..	..
Carbonic acid ..	..	..	..	..	..	..	0·90	..	..	..	..	..
Phosphoric acid ..	..	..	..	..	..	..	traces	..	..	..	..	..
Potash	1·90	2·29	..	3·31	..	..	3·87	0·91	1·54	8·53	..	1·30
Soda	..	..	..	..	..	..	0·56	0·44	..			
Manganese	..	..	..	..	traces	traces	traces	0·09	..	trace	..	..
Sulphate of lime ..	..	..	..	..	..	..	..	..	..	..	..	4·53
Phosphate of lime	..	..	..	..	..	..	..	..	..	..	..	0·72
Organic matter ..	..	..	..	..	..	..	4·39	traces	..	..	..	9·15
Loss and water ..	9·61	12·83	1·5	11·96	.	..	2·13	5·85	..	..	21·60	3·66
	99·96	99·38	100·0	99·36	99·34	99·45	100·63	99·89	88·69	99·15	100·00	100·00

All these clays will stand fire well, and are much used. In addition, the following are in common use for ornamental and moulded work, and for tiles:—Stone-ware, black and red clays, from Wareham; red and buff clays from near Tamworth, Staffordshire Potteries, Bishops Waltham, N. Shields, Aldrington and Brighton, Leeds, Huntingdon, Arley, Worcester, Tamar; red clays from Broseley (Shropshire), Ipswich, Penybont, Knutsford (Cheshire), Northwich, Farnham, Maidenhead, Bucknell (Berks), Norwich, and Pluckley (Kent). The Cornish, Devon, Dorset, and other clays which burn to a light colour, as a rule will stand a higher degree of heat than the red clays, and generally shrink less in the fire. There is great difference in the weight of clays when dried and ground; in some, as much as 25 per cent. All are improved by weathering, and, after tempering and mixing, by age. Many of the strong red clays become blue under certain conditions of burning, and some become readily discoloured. Great care is necessary in firing red ware to maintain a uniformity of tone, and avoid cracking and warping. Red terra-cotta in some cases is improved by combining two or more clays. Black, chocolate, and other dark colours have red clay as the base, to which is added calcined ochre, manganese, and other substances.

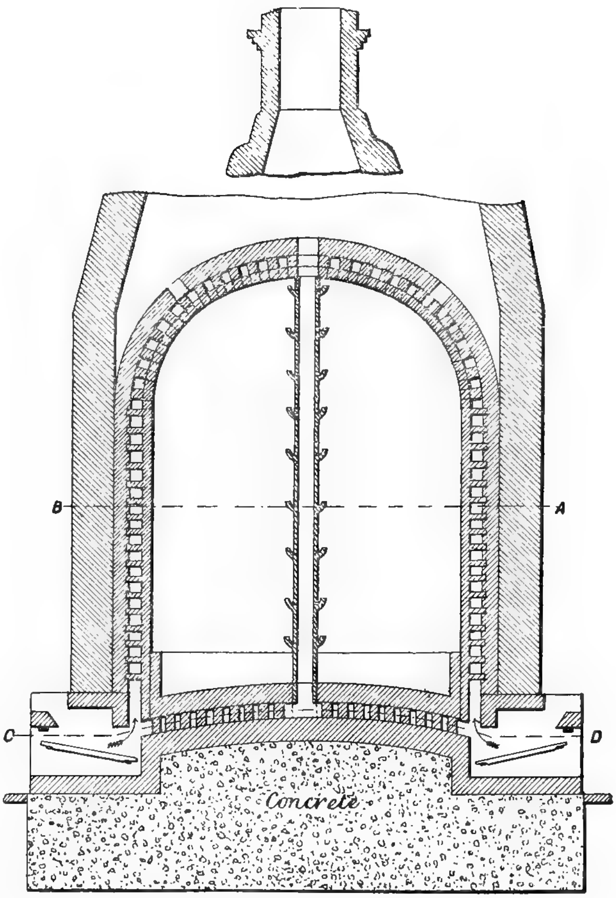
Many clays are very pure, and do not require washing; some, however, contain pyrites, or other substances which necessitate careful washing through sieves, or what is termed "slipping." Coloured bodies for terra-cotta or tiles should be always mixed in the slip state, and brought to a proper consistency for working on a slip-kiln. Many clay bodies are now, after slipping, passed through machines constructed to press out the superfluous water, and leave the clay in a pasty state fit for immediate use. Some manufacturers only partially dry the clay, then crush it in a rolling-mill, mixing with it ground potsherds, sand, &c., and then pass the whole through a pug-mill. Others dry the clay thoroughly, and grind it to powder between horizontal stones, mix what they desire with it, and then pug the whole, occasionally passing it twice through the pugmill. When different clays are combined in the dry state to make one body, it is important this should be done. Clays used for mouldings are often pugged as taken from the pit, and at once transferred to a moulder's or machine-worker's charge. It is not safe, however, to make very large pieces by machinery.

The material chiefly used in large terra-cotta to check warping, unequal shrinkage, and cracking, is ground burnt clay, old ware, or potsherds. This material is sometimes called by the workmen "grog," at other times "grit." It is ground and passed through sieves of various meshes to suit the character of the work in point of magnitude and delicacy of ornamentation. Clay is sometimes mixed, kneaded, and burned especially for this use. The proportions to be used vary according to the size of the pieces to be made, the quantity of other substances (if any) to be combined, and the fatness of the clay. After the clay is mixed and prepared by the mill, it should for all artistic works be well beaten with an iron bar, and what is termed "wedged," which consists in cutting a lump of clay with a wire, and slapping it together repeatedly to remove the air.

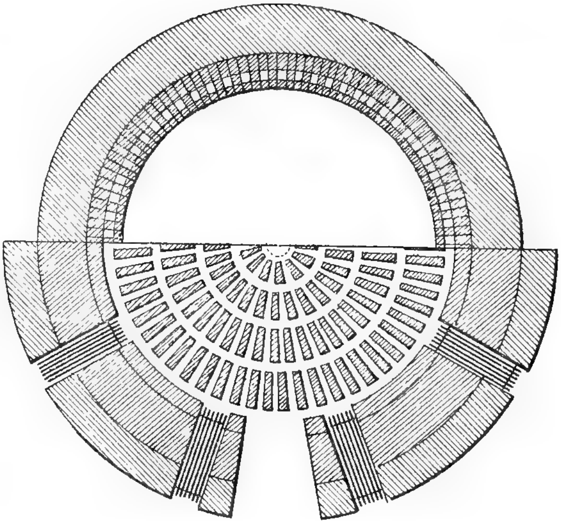
The other materials used besides clay and potsherds vary according to the clay, and the class of terra-cotta it is desired to make. Among these, sand is an important substance. Ground glass, china stone, and flint are often used. Generally clay itself forms, in light-coloured ware, about $\frac{2}{3}$ of the composition, and for good red clays, sand or flint is commonly all that is required to be added, unless the pieces are large.

Kilns. — Before entering

1158.



1159.



upon the subject of modelling, or moulding, it will probably be best to speak of the kilns for burning the ware (Figs. 1158, 1159). These are usually round in plan, with an internal dome and a conical chimney. They are lined with fire-bricks, and banded with iron, which is arranged to fold, and fasten over the door of the kiln, when the firing goes on. The number of furnace-holes around the kiln is determined by its size. Flues pass from the lower parts of the furnaces, under the floor of the kiln, and are commonly in connection with a fire-clay pipe-flue in the centre, as shown in Fig. 1158, which represents the section of a kiln with a continuous muffle, or inner lining, for the prevention of discoloration of the articles burned by vapours from the coals, also for the better protection of coloured and glazed articles. For all ordinary terra-cotta, this inner casing of brick or muffle throughout is not necessary. Small delicate models, whether plain or painted, enamelled or gilt, should be placed in saggers, if burnt in a kiln without a muffle. Articles beautifully wrought are made of stone-ware clay, painted, fired, and glazed with the vapours from salt, as in the manufacture of stone-ware. It has been found that burning by wood produces different results from firing salt-glaze with coal. Furnace-holes are constructed to check or prevent the formation of smoke. When a large volume of smoke is formed in the furnaces, it will pass through the kiln in full fire and red hot, and come out black at the top.

Modelling.—Before commencing any architectural work, full-size drawings should be made of all the details, and, to save errors, this had better be done to the terra-cotta scale of the wet clay, allowing for shrinkage in drying and burning; this with buff clays, is about 1 in. to 1 ft., but the extent of contraction after careful firing should be determined exactly, at the outset, before any work is set out, or model made. From the drawings, sections of the mouldings may be traced on wood or metal, for forming templates or running moulds, similar to those used in working plaster cornices. Such templates, worked against the edge of a rule fixed to a board or bench, can be used to form mouldings in clay, and, worked from a centre, for describing arches and circular forms. The clay used may be the terra-cotta clay itself, and this mode of working is the cheapest when a small quantity is wanted of a given moulding, as the whole may be described at one time. When the clay has become stiff, it can be cut into various lengths, and fitted with angles if necessary, and so left to dry for burning. If the mouldings are large, they should be hollowed out. A thickness of 2 in. is usually sufficient for the largest mouldings. Considerable attention should be paid to the drying of the mouldings, or they will warp, or get out of shape. By turning them about, face, and sides downwards, and then reversing their position, until they are dry, they may be kept true. The clay used in running mouldings in this way should not be coarser than would pass through a sieve of 20 meshes to the lineal inch, or the arrises will not be brought out sharply. Mouldings may be dried before burning, until they are hard enough to be rubbed true with a piece of burnt terra-cotta, as masons rub the surface of Bath and other stones. They seldom twist in the fire after perfect drying and rubbing, and the mitres and junctions can be delicately finished by the chisel, so as to fit with accuracy. This operation of perfect drying and rubbing applies to all plain terra-cotta surfaces, whether prepared by the process of running moulds, or by machines similar to brick-machines, or from plaster moulds.

Plaster of Paris models prepared by templates should be made to the required scale when a large repetition of the same object is likely to be required, and more than one plaster mould wanted for making clay impressions. Plaster is the best ground or framework for clay models of enrichments and bassi relievi, when more than one piece of the same ornamental design is required. The combined clay and plaster model are readily moulded with plaster in the ordinary way. If the model is entirely in clay, and full of undercut foliated work, say in alto relievo, or a statue, many pieces would be required in such a mould, and an experienced plaster-moulder only should be employed, or the clay model may be spoilt. It is best to make as few pieces as possible, and arrange to get, whenever practicable, all the small pieces into two outside cases, the back of a statue in one case, and the front in another case. Grease or oil should not be used in making plaster moulds for terra-cotta, as is done in the common way of making plaster piece-moulds for casting. A little clay and water, mixed about as thick as good milk, will answer all purposes for the prevention of one piece of plaster sticking to another in piece-moulding.

Original, life-size, terra-cotta statues are modelled and burned, without the process of moulding, by building up the clay in a cellular form, and working with the fingers and modelling-tools on the surface. Extended limbs should be made solid in the first instance, and when the clay is stiff, hollowed out, jointed with soft clay to the body of the figure, propped up with clay supports of the same stiffness and age as the mass of the statue, and slowly dried for the firing. Some difficulties and dangers arise in moving large statues into a kiln, and frequently they are finished by the sculptor in the kiln, which is for the time illuminated by gas.

Very large fountain-basins and vases are made by forming on a bench, with a trap-door in the middle, the core, or inside, with clay worked by a template from the centre. When the core is turned in this way, it should be covered with thin sheets of paper, and upon this paper the outer surface of the basin is turned with another template from the centre, by laying sheets of clay over the prepared surface of fairly uniform thickness, pressing and uniting this outer clay which forms the basin well together. The template will now turn the outside of the basin. When the clay has stiffened, ornament may be modelled on the surface, or pieces of enrichment, made from plaster moulds, may be luted on with clay slip. It will be observed that, during this process, the basin is upside down, and is resting partly on the clay core. After the clay has become tough, the trap-door in the centre of the bench may be removed from beneath, and the clay core pulled away in pieces, leaving the basin gradually to dry alone; when dry, it should be turned over very carefully, examined as to finish and truth of surface, and removed to the kiln, resting only on a roll or disc of clay at the bottom, leaving the rim and upper portion quite free for equal contraction in burning. Basins, vases, and other articles, 12–20 ft. in circumference, have been made sound and true in every respect in the way described.

Many persons have a just objection to the piracy of architectural details especially modelled for their own use. Working such details out originally in terra-cotta is a check to this piracy. If an artistic work is executed in marble or stone, a model in common clay is made and moulded, and a plaster cast is taken to guide the carver, and this rough model is often used for all sorts of cement and composition castings. But the terra-cotta clay model is wrought out, undercut, and finished at once by the sculptor and burned, and when only one or two designs alike are required, it is in a money sense the cheapest and best method of working. The following are a few of the forms which can be safely and economically made as original terra-cottas:—Altars, arches, architraves, balconies, brackets, bassi relievi, bosses, busts, columns, capitals, chimneys, crosses, cornices, coats-of-arms, finials, fire-places, friezes, park seats, key-stones, medallions, tracery, perforated panels, rustic work, tablets, tombs, animals, canopies, caryatides, festoons, statues, trophies, scrolls, corbels, date tablets, terminals.

When much repetition is required, the use of plaster moulds is common; now and then, for flat surfaces, metallic and wooden moulds are used. The workmen employed in making impressions in moulds are called "moulders." The plaster mould is usually dusted with a little finely-ground flint, grit, or sand, and the clay, having been properly prepared, is beaten out on a very thick block of plaster of Paris, to the required thickness, and then firmly pressed by hand on to the surface of the mould. If the mould is in two parts, or cases, both pieces are partially filled with impressed clay, the edges of such clay are scratched with a tool, moistened with water, and a little soft clay is placed over the edges, when one portion of the mould is lifted over the other, and squeezed down so that the luted edges join perfectly. The clay and the plaster mould remain undisturbed until the porosity of the plaster has absorbed a portion of the water from the clay, when the outside casings and the smaller pieces of the mould are removed, and the article pressed appears showing the joints or seams of the mould on the surface. These are in due time removed by a modeller, or careful finisher. If the pieces to be made are large, struts or cells are formed to strengthen them, as nearly all terra-cotta works are hollow. The hollow parts of architectural details are generally filled up with good stiff mortar, selenitic, Portland, or Roman cement, with fragments of brick or tile. Great care should be taken if Portland cement is used that it does not expand, which it is apt to do, sometimes cracking the terra-cotta.

A very large proportion of the articles made of terra-cotta are dried imperfectly, or in draughty sheds, and hence there are many twisted and unsightly pieces. A good drying-chamber or shed properly heated, and in proximity to the kilns, is a desideratum. More ordinary terra-cotta ware is injured in drying than is spoiled in the firing.

Employment of Machinery.—Terra-cotta mouldings or moulded bricks are sometimes made in a machine acting vertically with a die at the bottom, and as the clay passes from this die, it is caught by a board or palette, and cut off in given lengths, as drain-pipes are. At other times, mouldings and ashlar pieces are driven through dies, out of a brick-machine, cut off by wires and removed on palettes. The mouldings and the ashlar work, when stiff, are trimmed clean at the edges. Ornament pressed out of plaster moulds is sometimes luted or slipped on to the plain mouldings. The completeness of machine-work depends much upon careful drying. All these machine-made mouldings and ashlar work, if dried thoroughly, may be rubbed true, the same as Bath and other stones are treated, as before mentioned. Terra-cotta tiles 12 in. sq. have been made in great quantities by machinery, and rubbed as true as marble.

Fire-proof Terra-cotta.—By the aid of machinery, fire-proof terra-cotta for casing iron columns, girders, and for general construction of walls and floors, may be economically produced. Gas and other stoves, hearths, and backs for fire-places are made of fire-clay, coloured, and glazed. Stove-backs, ornamented with crests and coats-of-arms, have been made of fire-clay in which black oxide of manganese has been introduced, so as to produce, after burning and rubbing with black-lead, the appearance of cast-iron.

Some fire-clays are of a nice pale-buff colour, and free from specks of iron, from which, columns, pilasters, soffits, facias, and slabs could be made by machinery. Such work should be of greater thickness than ordinary terra-cotta, and should be contrived to fit together by mortise and tenon, with lap-joints luted with fire-proof cement, and filled in with fire-proof materials, so as to prevent the sudden destruction by fire and water of iron girders and columns, which almost always ensues in large fires.

All the buff clays used in ordinary terra-cotta are to a certain extent fire-clay, and will stand a temperature at which most of the red clays run down into a vitreous mass. Columns made hollow, of buff terra-cotta clay combined with fire-clay, were used by Sir Digby Wyatt to support girders, and at the same time to act as warming-flues through a building of three floors.

Strength of Terra-cotta.—The results of experiments made to ascertain the resistance of terra-cotta to a thrusting stress, comparatively with Portland and Bath stones and common stock brick, show that, as a building-material, it greatly exceeds all in ordinary use. A table recording these experiments, prepared by David Kirkaldy for J. M. Blashfield, and laid before the Royal Institute of British Architects by Charles Barry, is given on pp. 1588–9. (The specimens were bedded between pieces of pine ½ in. thick.)

Among the public edifices where terra-cotta has been very largely used during the past 30 years, are the following:—S. Kensington Museum, Duchy of Cornwall Office, Royal Mausoleum (Windsor), Victoria and Albert Museum, Sassoon Tower, Elphinstone Circle, and National Bank of India (Bombay), London & N. W. Station, Broad St. (London), Buckingham Palace, Sandringham House, Royal Albert Hall, Wedgwood Institute, India Office, Rolls and Record Office, Dulwich New College, Natural History Museum (S. Kensington), Law Chambers in Carey St, Fine Art Museum (Boston, U.S.A.), New Libraries (S. Kensington), Life Guards Barracks (Knightsbridge).

Tesselated and Tile Pavements.—Such pavements are frequently called mosaic, encaustic, and inlaid. Floors of tesselated work made of common clays are of great antiquity. The mosaic pavements so frequently met with in Roman remains in England are composed of fragments of tile and stones of various hues; the larger tesseræ for the outside margins are commonly clay, and the red invariably so. These pavements, from the inequality of hardness of the materials, have not worn uniformly in all cases.

A special feature in Mauresque mosaics, is the interlacing of one colour with another in the same device. A stanniferous glaze was commonly used by the Moors in the 13th century. The pieces forming their mosaic works, also their tiles with raised ornament, appear to have been pressed into plaster moulds. Glass mosaic, having a Mauresque type of design and colour, is commonly met with in the churches of Italy, and frequently in combination with porphyry. There are examples of this and marble mosaic in Westminster Abbey. Florentine mosaic is composed entirely of marbles, agates, and gems; the materials are costly, and the process of working it slow, but most beautiful pictures are produced at the studios for this art at Florence.

Several attempts were made in England in the beginning of this century to form tesselated pavements by combining marble and stone with coloured cements: Wyatt, Carter, Benasconi, Felix Austen, and Croggon, made attempts in this form, but with no great success. In 1836, Blashfield made ornamental pavements by combining Aspdin's and Parker's cements with mineral colours. This pavement wore well, and stood frost, but it looked dingy. The cements were mixed with water, placed in iron moulds, and screwed down to drive off part of the water from the cement, and so get the edges of the forms perfect. Inlaid tiles after patterns of encaustic clay tiles were so produced, and subsequently Blashfield tried coloured bitumen, but this material did not wear or look so well as the cement. Painted tiles were made in clay by Copeland & Co. at this time for Blashfield for terrace-steps. The tiles were so designed and made that, when combined, they formed a pattern 6 ft. in length. The colours were red and black. In 1839, an elaborate mosaic floor was made by Blashfield at Deepdene, combining the features of the ancient "opus incertum," the Venetian "pisé," and the common Italian "trazzo" floors. It is the largest floor of this character in England. The mosaic features were placed face downwards on a true bench, and backed with thin red tiles and cement, and thus formed into large slabs, which, when all properly bedded on a concrete floor, were rubbed down and polished.

In 1838, Routledge and Greenwood made buff terra-cotta pavement and tiles. The latter were inlaid with scagliola, and polished. In 1839, Singer of Vauxhall, assisted by Pether, made tesseræ for slabs and pavements, copying Moorish and Roman examples. Singer's process was to place clay, well kneaded and of various colours, and as near as practicable of uniform stiffness, in a machine, where, by means of levers, it was subjected to pressure, and made to exude from an aperture 6 in. by ½ in. As it protruded, it was cut into lengths of 3 in., and these small pieces were left for some days to dry. Fifteen or more were then laid one upon another, and a frame of corresponding size (across which were strained wires, crossing one another at regular intervals), sliding vertically on two uprights, was made to pass through them, cutting out by this motion 100 or more tesseræ. When any curved forms were required, the tesseræ were placed angle-wise in a groove, and a piece of curved metal was made to pass through a number of them placed together, which gave a coincidence of form in the parts divided. The tesseræ were then burnt, and put together on slabs of slate. The great hall of the Reform Club was executed by Singer with tesseræ thus

Test No.	Marked.	Description.	Dimensions.		Base Area.	Cracked Slightly.			Cracked Generally.			Crushed.		
						Total.	Per square inch.	Per square foot.	Total.	Per square inch.	Per square foot.	Total.	Per square inch.	Per square foot.
C.			H.	L. × B.	Sq. inch.	lbs.	lbs.	Tons.	lbs.	lbs.	Tons.	lbs.	lbs.	Tons.
638	No. 2. 15	Cube, solid	5·90.	5·88×5·90	34·69	238,960	6,888	442	255,350	7,361	473	282,520	8,144	523
639	„	„ „	5·92.	5·90×5·86	34·57	202,730	5,864	377	212,550	6,149	395	224,920	6,506	418
632	MG. 17	„ „	5·78.	5·72×5·74	32·83	132,340	4,031	259	188,840	5,752	369	237,180	7,224	464
633	„	„ „	5·68.	5·70×5·70	32·49	138,120	4,251	273	159,730	4,916	316	163,110	5,020	322
637	CT. 16	„ „	6·00.	5·68×6·21	35·27	128,150	3,633	233	184,240	5,224	335	222,870	6,319	406
636	„	„ „	5·90.	6·10×5·76	35·13	122,350	3,482	223	176,730	5,031	323	183,820	5,232	336
635	CA. 14	„ „	5·95.	5·85×5·80	33·93	133,630	3,938	254	168,110	4,954	318	189,520	5,586	359
634	„	„ „	5·95.	5·85×5·80	33·93	127,150	3,747	240	154,560	4,555	292	176,840	5,212	335
645	MG. 1	Hollow, filled *	6·20.	11·60×5·70	66·12	46,340	701	45	74,220	1,122	72	168,610	2,550	163
646	„	„ empty	6·20.	11·46×5·70	65·32	22,340	342	22	39,720	608	39	80,840	1,238	80
650	CT. 3	„ filled	6·30·	11·70×5·80	67·86	26,250	386	24	54,370	801	51	130,260	1,919	123
649	„	„ empty	6·25.	11·55×5·85	67·56	33,850	353	22	43,630	645	41	69,350	1,026	65
648	CA. 2	„ filled	6·25.	11·70×5·80	67·86	54,120	797	51	84,180	1,240	79	126,970	1,871	120
647	„	„ empty	6·10.	11·70×5·80	67·86	26,740	396	25	44,920	662	42	64,380	938	60
656	MG. 9	„ empty	5·75.	11·55×6·72	77·61	56,540	728	46	178,960	2,305	148	224,750	2,895	186
655	„	„ empty	5·70.	11·55×6·90	79·69	54,370	682	43	166,220	2,085	134	218,630	2,743	176
652	No. 2. 4	„ filled	5·73.	11·70×6·90	80·73	108,100	1,339	86	130,270	1,613	103	148,140	1,835	118
651	„	„ empty	5·75.	11·66×6·90	80·45	53,330	662	42	90,110	1,120	72	127,950	1,590	102
654	CT. 5	„ filled	5·70·	11·60×6·90	80·04	54,830	685	44	118,220	1,477	94	134,510	1,681	108
653	„	„ empty	5·80.	11·60×7·00	81·20	48,680	599	38	60,870	749	48	94,160	1,159	74
669	23	Solid	2·45.	3·40×3·85	13·09	174,120	13,302	855	181,840	13,891	893	188,120	14,371	924
670	22	„	2·80.	3·40×3·85	13·09	53,110	4,057	260	64,330	4,914	316	66,560	5,084	327
674	27	„	4·70.	5·10×2·00	10·20	21,635	2,121	136	51,550	5,054	325	84,380	8,272	531
673	28	„	2·70.	6·50×3·32	21·58	60,530	2,805	180	96,280	4,461	287	117,290	5,435	350

671	Red 20	Nearly solid	2·70. 9·00×4·12	37·08	72,250	1,948	125	98,320	2,651	171	119,870	3,232	208
672	26	,, ,,	4·10. 8·10×1·60	12·96	31,220	2,409	154	33,610	2,593	166	34,840	2,688	172
664	No. 2. 6	Hollow, filled	2·90. 11·90×3·50	41·65	47,060	1,130	72	72,140	1,732	111	146,730	3,523	226
663	,,	,, empty	2·90. 11·90×3·50	41·65	15,525	372	23	21,567	518	33	66,470	1,596	103
658	MG. 7	,, filled	2·85. 11·80×3·50	41·30	49,410	1,196	77	116,100	2,811	181	133,450	3,231	207
657	,,	,, empty	2·85. 11·80×3·50	41.30	16,685	403	25	24,455	592	38	70,775	1,713	110
660	CA. 10	,, ,,	2·90. 11·90×3·50	41·65	10,630	255	16	17,040	409	26	59,115	1,419	91
659	,,	,, ,,	2·90. 11·85×3·50	41·48	9,710	234	15	15,680	378	24	54,370	1,310	84
662	CT. 9	,, ,,	2·87. 11·90×3·50	41·65	7,160	171	11	13,110	314	20	53,550	1,285	82
661	,,	,, ,,	2·87. 11·90×3·50	41·65	6,305	151	10	12,938	262	17	34,715	833	53
668	RC. 8	,, filled	2·90. 11·70×4·00	46·80	36,555	782	50	70,415	1,504	97	118,350	2,529	162
667	,,	,, empty	2·90. 11·70×4·00	46·80	3,342	71	4	7,810	167	10	31,208	666	43
665	CA. 13	,, ,,	3·10. 11·85×4·00	47·40	6,655	140	9	19,880	419	27	35,420	747	48
666	,,	,, ,,	3·10. 11·85×4·00	47·40	6,178	130	8	14,844	313	20	31,980	675	43
640	MG. 11	Column	11·90. 6·60 dia.	34·19	163,122	4,774	307	222,610	6,511	418	258,370	7,572	486
641	,,	,,	12·00. 6·56 dia.	33·82	131,820	3,898	250	143,650	4,247	273	167,880	4,964	319
642	CA. 12	,,	12·00. 6·60 dia.	34·19	128,530	3,759	241	181,760	5,316	342	212,580	6,218	399
643	,,	,,	11·95. 6·60 dia.	34·19	44,840	1,311	84	68,720	2,010	129	88,940	2,601	167
644	Red 24	,,	15·50. 6·00 dia.	28·27	108,170	3,826	246	123,620	4,373	281	137,570	4,866	312
677	19	Hollow, empty	5·50. 18·00×9·70	174·60	44,120	252	16	67,540	387	25	99,880	572	67
675	21	Solid	1·00. 6·10×6·00	36·60	386,350	10,556	679	..	..	..	..	..	..
706	Portland Stone.		6·00. 5·95×5·80	34·51	151,280	4,401	283	156,820	4,544	292	156,820	4,544	292
705	,, ,,		6·00. 5·95×5·85	34·80	150,750	4,332	278	155,540	4,470	287	155,540	4,470	287
708	Bath ,,		5·92. 6·00×5·88	35·28	48,120	1,364	88	57,270	1,623	104	57,270	1,623	104
707	,, ,,		6·00. 5·90×5·90	34·81	45,270	1,305	84	54,880	1,576	101	54,880	1,576	101
710	Common Stock Brick.		2·50. 9·10×4·12	37·49	10,110	270	17	28,660	764	49	47,840	1,276	82
709	,, ,, ,,		2·50. 9·00×4·20	37·80	8,160	216	14	24,220	641	41	44,240	1,170	75

---

* "Filled" implies that the hollow portions were filled with Roman cement.

made, and ground down to a true surface. He also made a pavement for the court of the present Royal Exchange of similar tesseræ, but being laid down during winter, the cement gave way, and the whole was taken up and removed. Some of the pieces used for dados and Mauresque slabs were made out of plaster moulds, and these were often coloured and enamelled. These pieces of tesseræ were affixed to slabs of slate with plaster, and were much used for sides of stoves. About 1830, S. Wright of Shelton took a patent for making inlaid tiles after the fashion of the mediæval tiles; he sold his rights to Herbert Minton, who, assisted by the advice of Welby Pugin, produced the tiles so well known in connection with the name of Minton.

Inlaid tiles were largely made in England in the 13th, 14th, and 15th centuries, some later on. The oldest tiles are of red or brown colours, some few black, having ornaments painted on them with white or buff clays, and glazed. Other tiles have ornaments impressed on them in relief, possibly pressed in carved wooden or plaster moulds. This impress of ornament may have suggested the inlay of other coloured clays in an indented surface, and led to the running-in of slip, or thin clays of white, buff, black, or green, into the indented surface of the tile. The superfluous slip would have been scraped off when stiff, and the tile brought to a perfect face, and glazed and burnt. All these tiles seem to have been coated with a plombiferous glaze. They were made of various sizes, but are not often found more than 6 in. sq., and frequently are so designed that 4, 9, and 16 tiles are required in combination to form one pattern. Some of the best pavements of this sort were found at Salisbury, Winchester, Exeter, Bristol, Chichester, Oxford, and Gloucester Cathedrals; and in numerous old churches and other places in England they exist in great number. One of the most perfect old examples is the floor of the Chapter House, Westminster Abbey. They are frequently laid with marginal tiles quite plain, and sometimes with an inlaid border at the verge. The inlaid ornament usually affords a clue to the date of the tiles, as the type of the architecture of the age is seen in these fictile records. There is an artistic effect about the free sketchy way in which the designs are drawn, and the mottled appearance of the colour, which gives them a great charm, and over-rides the more precise outline and uniform tone of modern tiles.

The revival of this branch of the ceramic art has given rise to a purer taste in all that concerns domestic decoration, and induced ideas of cleanliness unknown before.

The modern mode of making encaustic or inlaid tiles is first by modelling the design from a drawing on a thin film of clay on a plaster ground, or by incising the ornament on a block of clay or plaster, and then pouring over the model, plaster of Paris to form a mould. Moulds from a hard plaster or a carved wooden model are sometimes made in brass, and a metallic frame is often the boundary of the plaster mould. Metallic moulds for patterns which are to be much repeated are the best and most economical. The clay for the body of the tile is pressed into a mould by a small screw-press; and the mould produces the outer form of the tile, and the ornament on the surface, at the same turn of the screw. After the tile has been pressed, and removed from the mould, it is allowed to become tough in dryness, before the operation of filling in the indented ornamental surface takes place. When the tile is thus far dry, a thin mixture of white, buff, or coloured clay is carefully poured over the indented parts; if two or more colours are to be poured in, stops of clay, or coverings, are used to check the running of one colour into another, and the respective colours are thus filled in one after the other. After filling in, the tile is placed again to dry, and when very stiff, it is carefully scraped over with a thin piece of steel, and all the coloured clay lying unevenly on the surface is removed. The ornamental features are then seen in sharp outline, and the tile is thoroughly dried for firing. There is a disposition in some clays, when so treated, to round on the face in drying and burning; this is checked by placing a thin layer of clay of a different refractory character on the back of the tile when it is first formed, and piercing holes through this layer of clay, to admit of the free egress of steam and fixed air. The modern practice is to glaze such tiles as are required to have an enamelled surface, by a second firing, after burning them first in the biscuit state.

Without trespassing upon the subject of porcelain buttons (see Buttons, p. 559), it may here be mentioned that, in 1840, R. Prosser, of Birmingham, obtained a patent for the manufacture of buttons by reducing the material of porcelain to a dry powder, and subjecting it to strong pressure between steel dies; the powder, being compressed into about a fourth of its bulk, becomes a compact substance, and can be at once placed in a kiln and fired. Prosser disposed of part of his interest in this patent to Herbert Minton, who then made some very beautiful china buttons and studs. In 1841, Blashfield saw them and learnt how they were made, and conceived that the button-making process might be extended to the manufacture of tesseræ and small tiles for pavements. A correspondence ensued between Blashfield and Minton on this subject, and the latter made some experiments, and sent Blashfield some 1-in. cubes, having a blue colour on one face and a white body. The blue colour was crazed and cracked. Minton made further trials, and succeeded in producing some very good blue and some white tesseræ, $\frac{3}{8}$ in. thick and $\frac{7}{8}$ in. sq.; these Blashfield placed together in the form of a Greek fret on a drawing-board face downwards, and poured Roman cement over them, pressing some flat roofing-tiles into the cement, and thus formed them into a small slab. When the cement had set, the face of the mosaic was washed, and this first piece of Minton's mosaic work was exposed to the weather during the whole winter, and received no injury from the frost.

Prosser enlarged his patent to cover the making of tesseræ and tiles, and began to make machines for Minton's use in this way, and entered freely into Blashfield's views. The latter suggested sizes of tesseræ and tiles, and colours, and the importance of gilt and enamelled tesseræ, and gratuitously provided Minton with designs of mosaic pavements and tiles, and copies of those in Westminster Abbey, subsequently calling to his aid Owen Jones, H. Kendall, and Digby Wyatt, and commencing with them a series of publications of designs. In 1843, the process of manufacture was exhibited by Prosser and Blashfield at a meeting of the Royal Society, when the late Prince Consort took great interest in the making of the tesseræ, and desired an account of the whole subject to be sent to him.

Minton hesitated to order machines for forming tesseræ and tiles beyond the sizes of 1 in., ½ in., and ¼ in.; but Prosser made the necessary tools, and in 1844–1845, tiles of large size and various shapes, and slabs 3 ft. long, were fabricated. Michael Hollins, the present proprietor of the tile works, laboured most zealously from the first in the fabrication of the raw material and colours.

Having related something of the early history of this important improvement in the ceramic art, which has brought about such vast changes in architectural decoration, and which is making every day fresh strides, we will enter upon a description of the machine first employed to make tesseræ, and which, with a few modifications, is still used for tesseræ and small thin tiles, a more powerful machine and hydraulic presses being used for large and thick tiles, and other flat surfaces, and for making bricks from powdered clay. The preparation of the powdered material may be explained in a few words. For tesseræ, it frequently consists of alumina, silica, and baryta, mixed with some metallic oxide for colouring matter. The difference between the new process and the old is that the clay or earthy material for making the tesseræ, tiles, or other articles, instead of being used in a plastic state, is used in dry powder. The materials may be of the same character, and, up to a certain stage in their combination, they undergo a like preparation. For example, they are mixed with water, and ground by machinery, to thoroughly incorporate them, and, in a semi-liquid state, are passed through fine sieves, to remove all coarse particles; and when this is done, the clayey paste is partially dried by the heat of a slip-kiln, and made up into balls, which, when perfectly dry, are ground in a mill; and the dry ground material, for fine surfaces, is passed through sieves, to prevent the risk of any coarse particle or dirt getting into the articles which are to be moulded.

Tiles must be classified rather by the processes of their manufacture, than by the materials of which they are composed. Tiles may be made by the same process, and yet may present as great a difference in texture as fire-ware on the one hand and vitreous stone-ware on the other. The body most commonly used is that of ordinary white earthen-ware; but for coloured tiles, and for a backing to a surface of superior quality, mixtures of local marls and fire-clays are largely employed. There are two principal processes, which may be distinguished as the wet process and the dry process. By the former, tiles can be made by hand, or by mechanical pressure; by the latter, by mechanical pressure only. In making plain tiles by the wet process "bats" of plastic clay are prepared in the ordinary way by manual or mechanical "batting," and are either cut to any required dimensions, or are beaten into a metallic mould. Tiles made as described are burnt in saggers, and reburnt after dipping in white or coloured glazes. The backs of tiles, whilst still plastic, are always impressed with small holes or depressions, which may form a key for the cement when they are applied to walls or other surfaces. So-called "Palissy" and "majolica" tiles are made from plastic clay "bats," which have received a raised pattern on their surfaces from a depressed pattern sunk into the mould in which they have been pressed. After first burning, the Palissy tiles are dipped into transparent coloured glazes, and the majolica tiles into opaque enamel slips.

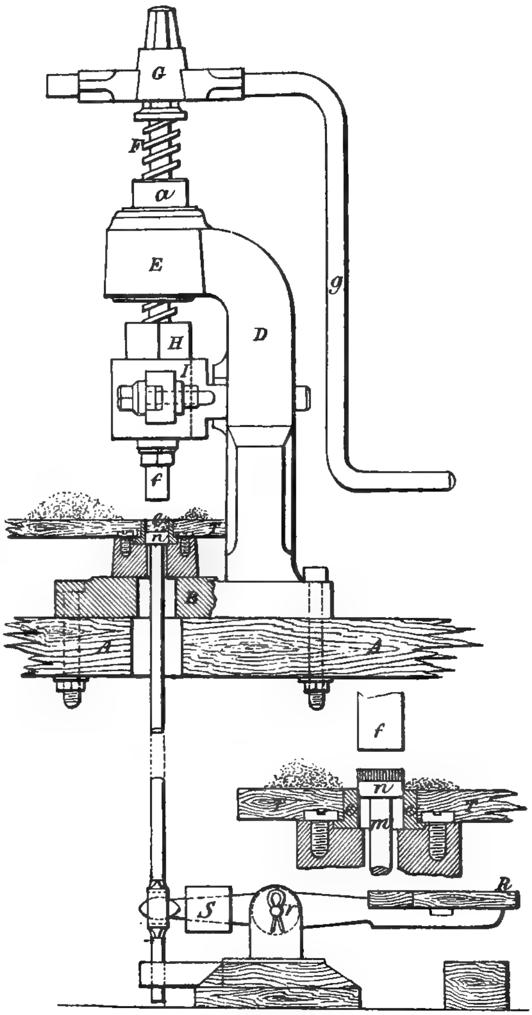
The dry process consists in consolidating clay powder by mechanical pressure. The clay powder, having been damped, is placed upon a metallic block of the size of the tile to be produced, surrounded by a movable collar, and is compressed by the descent of a plunger into the mould so formed. The pressure is communicated to the plunger by a vertical screw, and the momentum is obtained from a horizontal fly-wheel or weighted arm. The compressed powder is removed by means of a pedal, which lowers the collar or edge of the mould. The tiles thus produced may be either large or small, according to the power of the presses employed. Small tiles and tesseræ are made by girls in small hand-presses. The moulds can be so made that several tesseræ can be pressed at one motion. The compressed tiles are burnt for biscuit and glaze in the same manner as those made by the wet process. The compression of powder as a means of manufacture is not now limited to the production of tiles; at the present time, plates and gallipots are being made by an application of the same process. Coloured patterns may be inlaid in tiles by either process.

The colours employed are clays coloured naturally, or by the artificial admixture of the oxides of iron, nickel, manganese, or cobalt.

The wet process consists in forming a pattern in relief in plaster, and framing and backing it in a metallic support. Into the mould thus formed a thin bat of white plastic clay, backed with a clay of inferior quality, is pressed, and receives from the plaster mould a depressed pattern. A layer of white clay is then spread upon the common clay in order to counteract any contortion arising during firing from a disagreement between the common clay and the white clay on the face. The tile is heated until it can readily be removed from the mould. Into the depressed pattern on the surface, coloured clay slips are instilled from suitable vessels, and when the excess has been removed by scraping, the pattern is discovered.

The dry process is a further application of that already described. Upon the central block, a pattern is dusted with powdered clay through a thin metallic stencil-plate; the collar is then raised, and a layer of clay is inserted, and compressed by the descent of the plunger; a layer of inferior clay is next added and compressed; and finally a layer of the same clay as that used for the surface, the collar being raised to receive each fresh layer. The removal of the tile is facilitated by the depression of the collar. The same results may be obtained both for plain and inlaid tiles, by raising or depressing by a pedal a movable base working inside an immovable collar.

1160.



One of the earliest machines and moulds used for moulding articles of a small size in powdered clay is represented in Fig. 1160: A is the wooden bench on which the whole is fixed, the bench being sustained on legs standing on the floor; B D E, the frame, formed in one piece of cast-iron, the base B being fixed on the bench by screw-bolts, the upright standard D sustaining at its upper end the boss E, wherein the nut or box *a* is fixed for the reception of the vertical screw F; the screw F works through the box *a*, and has a handle G *g h* applied on the upper end of the screw; the handle is bent downwards at *g*, to bring the actual handle *h* to a suitable height for the person who works the machine; by pulling the handle *h* towards him, the screw F is turned round in its box *a*, and descends. The lower end of the screw F is connected with a square vertical slider H, which is fitted into a socket I, fixed to the upright part D of the frame, and the slider H is thus confined to move up or down with an exactly vertical motion, when it is actuated by the screw. Thus far, the machine is an ordinary screw-press, such as is commonly used for cutting and compressing metals for various purposes.

The tools with which the press is furnished consist of a hollow mould *e*, formed of steel, the interior cavity being the exact size of the article to be moulded. The mould is firmly fixed on the base B of the frame, so as to be exactly beneath the lower end of a piston or plug *f*, which is fastened to the lower end of the square slider H, and the plug *f* is adapted to descend into the hollow of the mould, when the slider H is forced downwards by action of the screw F, the plug *f* being exactly fitted to the interior of the mould. The bottom of the mould is a movable piece *n*, which is exactly fitted into the interior of the mould, but which lies at rest in the bottom of the mould during the operation of moulding; but afterwards, the movable bottom can be raised by pressing the foot upon one end R of a pedal-lever R S, the fulcrum of which is a centre-pin *r*, supported in a standard resting upon the floor; the end S of the lever operates on an upright rod *m*, which is attached at its upper end to the movable bottom of the mould. A small horizontal table T is fixed around the mould, and on that table, a quantity of powdered clay is laid in a heap in readiness for filling the mould.

The operation is very simple; the operator holding the handle *h* with his right hand, puts it back from him, so as to turn back the screw F, and raise the slider H and plug *f* quite out of the mould *e*, and clear above the orifice of the mould, as shown in Fig. 1160. Then, with a bone spatula held in the left hand, a small quantity of the powder is moved laterally from the heap, along the surface of the table T, towards the mould *e*, and gathered into the hollow of the mould with a quiet motion, so as to fill that hollow very completely; and by scraping the spatula evenly across the top of the mould, the superflous powder will be removed, leaving the hollow cavity of the mould exactly filled with the powder in a loose state. The handle *h* being drawn forwards, with a gentle movement of the right hand, it turns the screw F, so as to bring down the slider H and plug *f* into the mould upon the loose powder, and begins to press the powder with a gentle motion, without any jerk, in order to allow the air contained in the loose powder to make its escape; but the pressure, after having been commenced gradually, is continued and augmented to a great force, by pulling the handle strongly at the last, so as to compress the earthy material upon the bottom *n* of the mould, into about one-third of the space it had occupied when it was in a state of loose powder.

The handle *h* is put back again, so as to turn the screw F, and raise the slider H and plug *f* until the latter is drawn up out of the mould *e*, and clear above the orifice of the mould; and immediately afterwards, by pressure of the foot upon the pedal R of the pedal-lever R S, and by action of the upright rod *m*, the movable bottom *n* of the mould is raised in the mould *e*, so as to elevate the compressed material which is resting upon the bottom *n*, and carry it upwards out of the mould *e*, and above the orifice of the mould, when the compressed material can be removed by the finger and thumb. The compressed material so withdrawn is a solid body, retaining the exact shape and size of the interior cavity of the mould, and possessing sufficient coherence to enable it to endure as much handling as is requisite for putting a number of them into an earthenware case or pan, called a sagger, in which they are to be enclosed, according to the usual practice of potters, in preparation for putting them into the potter's kiln for firing.

After the firing, the articles made are in what is called the "biscuit" state, and such as are required to be glazed are dipped into the fluid glazing-compound, and are again fired. All small pieces made by this dry-powder process may be glazed at the first fire by introducing a glazing-composition within the saggers. The materials forming small articles may be so prepared that the articles become partially vitrefied by the heat of the kiln.

All articles made from powdered clay contract less than those made from wet clay, and are more even on the surface; and time is saved by using a dry instead of a wet material. Articles of the same form are more uniform in size, and join and fit at edges and angles with greater exactness.

Encaustic tiles, as well as plain flat tiles, are made from dry powder. A thin piece of metal, with the pattern cut out, and fitting exactly over the indents pressed in the tile, is laid carefully over it, and then some coloured powder is spread over the metallic pattern, and pressed by a screw into the indented parts. The thin metallic plate is removed, and the superfluous clay lying about the surface of the tile is scraped off with a piece of steel, to fully bring out the design, as is done in making these tiles in the wet state. Tiles may be made in this way of half the thickness of those formerly made from wet clay, and of every geometrical form. It would have been impracticable to produce tiles at small cost for covering walls, as is now commonly done, by the old way of working.

Tiles only ½ in. thick of special forms are made for paintings, and are laid together; and figures of life size are drawn on them in a free spirited manner, and painted. These tiles are then fired again to fix the colours on the glaze. Sometimes colours are printed or painted on the biscuit tile, and it is then fired to harden on the colour, and is afterwards glazed. Every kind of flat ornament in bas-relief can be pressed in powdered clay and enamelled. There are fine examples of mosaic and tile flooring, and of tile wall decoration, in the South Kensington Museum, suggestive of the use of this art in many ways; and in several of the new restaurants and hotels, are special examples of its use.

In this country, where we have every variety of clay, and all the other materials necessary to make semi-vitreous forms of all colours, fitted for the use of the architect and civil engineer, and known to resist the severities of this climate better than granite, marble, or stone, it is remarkable that greater attention is not given to the use of architectural pottery. By the aid of machinery, are produced bricks, of good shape and with true surface; also plain moulded bricks, for string courses and cornices; and from plaster moulds, foliated mouldings and enrichments to combine with such bricks; and as the description of the new mode of making flat surfaces from dry powder, shows that mosaic and inlaid decoration, either in biscuit or enamelled ware, can be made to aid decoration at moderate cost, it is to be hoped that the example set by a few architects who have freely used these materials may be generally followed, and that the costly material, stone, which soon becomes dingy, and gives way to frost and the atmosphere of large towns, will be less in fashion.

Wares rendered Translucent by the fusion of an Incorporated Felspathic Glass.—The origin of the manufacture, in England and on the Continent, of every sort of translucent ware, was the wish to produce a facsimile of Chinese porcelain. The desired translucency has been attained with greater or less success in a variety of ways. The *pâte tendre* of Sèvres was in reality a glass, rendered sufficiently plastic by artificial admixture to be manipulated as clay, and fired at a temperature high enough to fuse the glass, but not so high as to injure the form of the ware. The resultant ware was so fragile, and the difficulties of manipulating the mixture, of supporting the ware during firing, and of adjusting the temperature of the kilns, were so great, that the manufacture of *pâte tendre* was gladly abandoned on the discovery of kaolin at St. Yrieix. English china is rendered translucent by the addition to a pure plastic clay of a considerable proportion of glass-forming materials, but the proportion is so regulated that, although the ware does not require excessive heat for its firing, its plasticity is sufficient to facilitate manipulation; moreover, the balance of fusibility and plasticity is so adjusted as to allow the introduction of sufficient calcic phosphate to reduce the shrinkage of the ware to a minimum, and at the same time greatly to add to its brilliancy. English china is easily worked, easily fired, and easily decorated. The hard porcelains of Berlin, Sèvres, and other European manufactories, resemble true Chinese porcelain in being produced from purely granitic materials. They differ from English china in being more difficult to manipulate, in requiring a higher temperature for firing, and in being less susceptible of receiving colour and other forms of decoration. They are superior, however, in their power of resisting corrosion, and of withstanding extreme changes of temperature.

The physical structure of translucent wares may be described as that of a transparent glass, holding opaque infusible particles of kaolin or other substances in suspension. Microscopic examination of a thin plate of hard porcelain reveals opaque rods, granules, and fragments of quartz, and spherical bubbles, bound together by a vitreous cement. The want of transparency is caused by the repeated reflection and refraction of light by these obstructive particles. The chemical nature of the different translucent wares is best illustrated by reference to the table of analyses (p. 1558). The proportions of alkalies, and of calcic, ferric, and magnesic oxides reckoned together are, approximately, in English china, 12; in Parian, 8; in Sèvres, 8; in Chinese, 7; and in Berlin and Japanese, 4. Of the alkaline constituents of Japanese porcelain, the sodic oxide is in excess; whereas in the case of Chinese porcelain, potassic oxide preponderates.

The raw materials used in the manufacture of hard porcelains are kaolin and felspar, or a felspathic mineral. The felspathic constituent or *petuntze* of the Chinese potters is potassium felspar, the orthoclase or adularia of mineralogists. The general processes of manufacture and manipulation in China and Japan are similar to those employed in Europe, although of a rougher character. Homogeneity is procured in the prepared mixture by repeated treading, and the mixture is always stored for a considerable time before being worked into ware. Hand-driven throwing-wheels are employed, and dried clay is used for moulds in the place of plaster of Paris. The glaze, which is made of felspar and lime, requires an intense heat for its fusion. There are few metallic oxides, except that of cobalt, which can withstand the requisite temperature, and it is therefore necessary to apply the less stable colours in the form of enamels upon the glaze, and to fuse them at a lower heat. The wares are generally subjected to a moderate fire before the application of the under-glaze colour and the glaze, although it is possible to fire at one time for biscuit, under-glaze colour, and glaze.

Sèvres hard Porcelain.—The raw materials used at Sèvres are kaolin from St. Yrieix, and chalk. The kaolin in its natural condition contains a considerable but varying proportion of felspathic sand. If the raw kaolin be exposed to an intense heat, it fuses to an opaline glass. In order to regulate the fusibility of the resultant ware, it is necessary first to separate the felspathic sand from the kaolin, and then to remix it in proper proportions. Separation is effected by agitating the raw kaolin with water in a suitable receptacle, allowing the heavy felspathic material to deposit, and drawing off the suspended kaolin into a second or series of receptacles, where it is gradually deposited, and from which the water, together with the floating and soluble impurities, may be run off from above. The felspathic sand is collected and ground with water in a mill with stone runners. The chalk is also ground, and the kaolin, felspar, and chalk, after passing a succession of sieves, are mixed together by measure in a liquid condition. The liquid mixture is consolidated partly by the expression of the water through a filtering medium of prepared linen, and partly by absorption of the water by plaster of Paris. The paste so formed is kneaded and beaten upon slabs of plaster of Paris, moulded into lumps, and stored in cellars for future use. The average proportion in which the three ingredients are mixed is: kaolin, 48; felspathic sand, 48; and chalk, 40. The comparatively large proportion of felspar and lime renders the mass deficient in plasticity. To partially counteract this defect, parings of unburnt ware are mixed with the dried and pulverized paste. This mixture is again carefully kneaded, and incorporated with sufficient water to produce the amount of plasticity requisite for manipulation. The processes of throwing, pressing, moulding, and casting, are similar to those already described, although modified in certain respects to suit the nature of the mixture. The mixture is less plastic, and more liable to defects from deficient homogeneity, than is the case with the mixture for English earthen-ware and china. In throwing, it is customary to subject the mass of paste, after being kneaded, to a preliminary moulding on the wheel, in order to ensure the regular aggregation of the constituent particles; it is also usual to allow the substance of the article in the rough greatly to exceed that of the finished pattern, provided the internal diameter remains the same, so that the exterior may be pared away by turning, and signs of unequal pressure be removed. The paste is prepared for pressing and moulding, by the passage over it of a wooden roller running upon guides; and the bat of paste is raised from the bed of plaster of Paris upon which it has been rolled, by means of an underlying film of skin or other material. In casting, the liquid paste is allowed to remain in the mould for a considerable time.

After manipulation, the wares are gradually dried, preparatory to burning. The ovens employed at Sèvres are each divided into two kilns, an upper kiln for burning biscuit ware, and a lower kiln for burning the ware which has been dipped in glaze. The biscuit- and glaze-kilns are separated by a perforated floor, through which, the surplus heat from the glaze-kiln passes into the kiln above. The heat and draught of the kiln are very intense; there is little smoke, and the ash is entirely dissipated. The fuel principally used is wood, and every precaution is taken to prevent dust.

The wares, whether for the biscuit- or glaze-kiln, are placed in saggers, and rest within the saggers upon flat ground slabs, made of a refractory clay dusted over with flint or fire-clay slip, and bedded evenly in sand. The saggers are built up by plumb line, with every precaution to secure the wares resting perpendicularly. The firing is regulated by the removal at stated intervals of small test-pieces of both biscuit and glazed ware, of the same composition as that used throughout the kiln, which have been previously placed in saggers from which they can be readily withdrawn from the outside. There are three stages in the management of the kiln: the gradual heating for the removal of moisture held by the body or glaze; the actual baking of the body, and fusion of the glaze; and the annealing of the glass in the body of the ware, as well as in the glaze. The firing may last 30–45 hours, and the kilns may remain closed after the firing, to allow of the gradual cooling of the ware, for a period of 5–8 days. The entire shrinkage of hard porcelain amounts to about 17 per cent.

Glaze.—The material used for the glaze is a natural mixture of felspar and quartz, and is known as pegmatite. Its average composition is silica, 74·3; alumina, 18·3; potassic oxide, 6·5; calcic oxide, 0·4; magnesic oxide, 0·2; water, 0·3; and it may be approximately represented by the formula $2(Al_2O_3,3SiO_2)+K_2O,3SiO_2$. It is therefore an ordinary glass, to which a second equivalent of aluminic silicate has been added, and the transparency of which is destroyed by the excess of infusible material.

Each fresh supply of pegmatite is tested in order to ensure a constant result. For use, the pegmatite is first crushed under vertical grinding-wheels turning upon a revolving base. It is then ground with water in a mill with stone runners, and when reduced to a sufficient degree of fineness, is drawn off, sifted, agitated in the presence of magnets, in order to remove particles of iron, passed into a receptacle, and maintained in suspension by constant agitation.

During the long process of grinding with water, great care must be taken to prevent a sudden precipitation of the material, either through the slackening or sudden stoppage of the stones. The tendency to precipitation may be retarded by mixing a small quantity of acetic acid with the water. The various mills at the Sèvres works are moved by water-power. Into the suspended pegmatite, the biscuit ware is dipped, care being taken that no part of one piece remains in the glaze longer than another, and that the thick wares shall be dipped in a thin glaze, and the thin in a thick. The parts of ware which have been held in the dipper's hand are retouched with a brush dipped in the glaze. The wares are replaced in saggers, and the saggers are placed in the lower division of the oven, the heat of which is more intense than in the biscuit-kiln. The entire absence of lead renders the glaze when fused exceedingly hard and durable; it is bluish in tint, and cold to handle. The grey tint of the body and glaze is due to the reducing action of the atmosphere of the kiln. The glaze is transparent, and rather more fusible than the body, but becomes thoroughly incorporated with it, and, from its similarity of composition, expands and contracts uniformly with the paste. The bases of ware when removed from the saggers are rubbed smooth with sandstone. Owing to the difficulty of manipulating the paste, it is customary to build up elaborate vases from distinct pieces, which are joined together by metallic fittings; this especially applies to feet and handles.

Parian and Belleek.—The nearest British representatives of true porcelain are Parian and Belleek. The materials generally used for Parian are kaolin, felspar, and small quantities of Cornish stone and ball-clay: the analysis of an average sample of Parian gives—silica, 54·8; alumina, 36·21; alkalies, iron, and other ingredients, 8·8. In some cases, the composition and preparation of Parian approaches closely to that formerly employed at Sèvres in the production of the *pâte tendre*. A glass is first formed by the fusion of a mixture of sand, felspar, Cornish stone, and potassic carbonate; this is run into water whilst still hot, broken up by the action of the water, and ground with water in a mill with stone runners. One part of the glass is mixed with about three parts of ground felspar and three parts of kaolin. A hard Parian may be made from a mixture composed of 60 parts felspar, 30 kaolin or china-clay, and 10 ball-clay. The Parian mixture is used in the liquid state, and the ware is fashioned by the absorption of the water from the mixture, and the consequent deposition of the paste upon the inner surface of dry plaster of Paris moulds. Vases and statuettes of the greatest delicacy may be produced by these means. The contraction of Parian in the process of solidification by heat is greater than in any other ware, and amounts to $\frac{1}{5}$–$\frac{1}{3}$ of the entire mass. It is worked in a state of perfect liquidity, and is rendered quite vitreous by fusion. The shrinkage is greater in the height of the ware than in the width, owing to the influence of gravitation. In making models for the moulds in which the wares are cast, provision must be made to counteract the inequality of contraction, and to bring the contraction to a common centre.

In reproducing a human figure, or group of figures, every limb is cast singly in a separate mould, and the whole is built up piece by piece, and cemented together in the green state by the interposition of liquid slip. Each mould is in two pieces, fitting closely together, and fixed by projections on one side protruding into corresponding depressions on the other. An opening is left in the middle of the upper part of the junction of the two sides, through which the liquid mixture can be instilled from a suitable vessel. The cavity of the united mould is filled and refilled as the water is absorbed, and until a sufficient thickness of paste has been deposited. So soon as the paste has become solid by absorption, the moulds readily deliver. The wares are burnt in specially-prepared saggers, and are supported in every direction by carefully arranged props made of refractory clay. The drapery of figures may be reproduced by spreading lace, or some fine textile, upon a slab of plaster, covering it with a layer of liquid paste, wrapping as required upon the figure, and simultaneously solidifying the paste and destroying the fabric by the fire to which the figure is exposed.

The creamy tint of English Parian is due to the formation in the body of the ware of a glass fused in an oxidizing atmosphere, and tinted by the ferric oxide naturally incorporated with the constituent materials. Foreign Parian has generally a greyish tint, owing to the reductive atmosphere of the kilns in which it is fired. The name of Belleek is commonly given to a species of glazed and lustred Parian, but the genuine ware is made from a mixture of kaolin and felspar artificially prepared from red orthoclase granite, and which has the property of assuming when fired a natural enamel or egg-shell film.

Artificial Porous Ware.—Porous ware is required for several purposes, especially for water-coolers and the inner cells of galvanic batteries. The principle upon which this manufacture is based is the introduction into the clay mixture of a proportion of some organic substance which will be destroyed by heat. The substance generally used is saw-dust. As the battery-cells are required to be exceedingly regular and thin, they are formed by the process of absorption or "casting" which has been already described (compare Parian). A clay containing an appreciable quantity of calcic oxide is unsuited for the manufacture of battery-cells. The moulds employed in the process of casting have constantly to be replaced, as they are subject to damage, by reason of the repeated absorption and evaporation of large quantities of moisture.

English China.—English china is generally of a dead or creamy-white colour, is translucent, and is apparently less cold to the touch than hard porcelain. The glaze is soft, and the ware will not resist extreme variations of temperature. The mixture for English china is manipulated and fired with greater facility and certainty than would be possible with simple granitic materials, and the resultant ware is adapted to a greater range and brilliancy of decoration than is applicable to a harder and less manageable composition. The materials employed are China-clay, or kaolin, ball-clay, Cornish stone, flint, and calcic phosphate, together with, in some cases, a small proportion of steatite, which consists of 63 silica, 33 magnesic oxide, and 4 water. The translucency of English china is due to the fusion of the felspar contained in the Cornish stone. The calcic phosphate performs many useful functions. In addition to reducing shrinkage, and enhancing the whiteness of the ware, it enables it by its infusibility to stand the fire requisite for the vitrification of the felspar, and adds lightness without materially affecting translucency. An analysis of a sample of Worcester china gives: silica, 38·88; alumina, 21·48; calcic oxide, 10·06; sodic and potassic oxides, 2·14; calcic phosphate, 26·44. Every manufactory has a different mixture for china, but the following may be taken as an average specimen: kaolin, 31·00; Cornish stone, 26·00; calcic phosphate, 40·50; flint, 2·50. The glaze is composed of a fused glass, ground and added to a mixture of Cornish stone, or felspar and plumbic carbonate. A glaze for a body composed as described might consist of 60 parts of a glass formed of—Cornish stone, 48; borax, 24; calcic carbonate, 20; potassic nitrate, 4; and sand, 4; added to plumbic carbonate, 16; and Cornish stone, 24.

In selecting materials both for the body and the glaze, the greatest attention is paid to their purity, and freedom from iron.

The processes employed in preparing the materials and manipulating the paste are similar to those already described under the head of Earthen-ware (p. 1573), but carried out on a smaller scale. The plastic clays are broken up by agitation with water, and the Cornish stone, calcic phosphate, and flint are ground with water under stone runners. The grinding-pans measure 10 ft. in diameter and 3 ft. in depth, and are paved with small blocks of chert-stone. The different materials, suspended in water, are sifted, and run by measure into a large receptacle, in which they are mixed and kept in agitation by revolving arms, carrying magnets, which attract and withdraw from the mixture any particles of metallic iron that may be present. The mixture is thence pumped into a filter-press, which is generally of a lighter and simpler construction than that used for earthen-ware. Pressure is applied by a hand pump, and the sacks are connected by central fittings, which, when united, form a single central tube through the entire series of sacks. When the paste is taken from the sacks, it is subjected to repeated beating, turning, and kneading, before it is considered to be in a proper working condition.

Another method of procedure is to dry the liquid materials separately by evaporation on a long shallow stone reservoir heated from beneath, and to mix the separate ingredients in the dry state by weight, to remix them with water, then to pump the liquid mixture first through a series of sieves, next through a series of stationary electro-magnets, and finally into the filter-press. The ingredients of the glass, which forms the largest constituent of the glaze, are mixed and introduced into the furnace represented in Fig. 1152. When melted, it is run from the furnace into water, broken up, dried, ground, and mixed by weight with the plumbic carbonate and ground Cornish stone. The mixture is then ground with water in a mill similar to, but smaller than, that used for grinding the hard ingredients of the body, until such time as the liquid glaze will pass a silk lawn containing 4000 meshes in 1 sq. in. The ovens and saggers are similar to those used for earthen-ware. The wares are bedded in the saggers in calcined flint, and the saggers are built up in airtight columns by the insertion of rolls of moist clay. The kiln for biscuit-firing takes 40–50 hours to fire, and about 48 hours to cool; the glaze-kiln takes 15–20 hours to fire, and about 36 hours to cool, and to allow the glaze to become annealed.

Decorative Processes.—The decorative effect of pottery is due to form, surface, or colour. Decorative form may be due to the taste and manual skill of the thrower, or, if the ware be moulded, pressed, or cast, it may originate with the art of the designer of the model for the mould. Ware, after receiving its outline from the thrower, and whilst still retaining plasticity, may have its form compressed, or indented, and its edges waved or crimped by the fingers, and according to the fancy of the artist. Ware may also be built up of detached pieces, as in the case of fine basket-work, and of imitation flowers. In the former, threads of clay, expressed through a stencil fixed in the base of a cylindrical screw-press, are twisted and cemented together, laid upon a plaster block of the shape which the interior of the basket-ware is intended to possess, and hardened by burning; in the latter, each petal is made separately by hand, and cemented together by liquid slip. The mouths of vessels may be artistically shaped by the insertion of "forms" made of burnt stone-ware or china.

The colour in the body of a ware may be natural or artificial, and may be mechanically or chemically combined. It is due to the presence of a metallic oxide, and the colour may either be the actual tint of the anhydrous oxide, or the tint which a glass assumes when fused with the oxide. The red of terra-cotta is caused by the presence in the natural clay of ferric oxide; and the buff and paler tints, by a smaller proportion, amounting to 1–3 per cent., of the same oxide, or by a larger proportion intermixed with lime or magnesia. The tint of ivory and cream-coloured ware is due to a glass coloured yellow by a minute trace of ferric oxide, and intimately mixed throughout the body. The mixtures for cream-colour and ivory are respectively the same as those used for earthen-ware and china, with the difference that clays are used containing naturally a slightly higher proportion of ferric oxide, and that sand is sometimes substituted for flint.

In order to facilitate the colouring of stone-ware by the presence of artificially coloured glass, as for instance in making a blue ware by the addition of cobaltic oxide, it is necessary to add Cornish stone to the clay, so as to render the body vitreous, and to supply a flux for the colouring oxide. Wedgwood's fine "jasper" ware is an artificial mixture of the same character, but containing a large proportion of baric sulphate. This substance serves the double purpose of resisting fusion, and of reflecting any colour that may be incorporated in the body of the ware. An average mixture is, baric sulphate, 57·1; baric carbonate, 4·8; flint, 9·5; clay, 28·6. The ware is unglazed, has a crystalline surface, is vitreous throughout, and may be coloured in the same manner as a glass. The sage-colour is due to chromic and cobaltic oxides; the drab, to nickel oxide; and the dove-colour, to cobaltic and manganic oxides. Stone-ware may be tinted by mechanical mixture with certain oxides. Thus ferric oxide gives a red, brown, or chocolate; manganic oxide, a black; and uranic oxide, a yellow. Differently coloured clays may be so kneaded and worked together as to present a good imitation of the grain and colours of marble. The costly Henri-Deux ware may be reproduced by inlaying coloured clays in patterns, stamped or engraved in separate bats of plastic clay, adjusting the separate bats in a mould, and uniting them by a common backing of clay, so that they are made to combine, and assume the form of the mould. The body is generally white; the inlaid ornament, brown and black; and the glaze, a warm cream-colour.

A decorative surface may be produced by impression, incision, or application. Impressed decoration may be transferred from the surface of a mould, or may be directly produced by a stamp or seal, or by a pattern cut in relief upon the edge of a small revolving wheel; by the repetition of the impression of a stamp, the effect of a diapered background may be obtained. A moulded pattern may be cut through with a knife, so as to imitate coarse basket-ware; and the delicate tracery of perforated ware may be produced in the same way, but with finer implements and greater skill. Lattice-work, executed in a similar manner, may be applied over depressions, or upon the surface of vessels which still retain their plasticity. A coloured clay is sometimes introduced into moulded depressions, and the surplus is removed on the lathe.

After a vessel has been thrown, patterns may be scratched upon it with a graver; if the clay be still moist, a ridge will be left by the tool on each side of the incision; the ridge, however, will not be formed if the clay be already dry. If colour be afterwards applied, the ridge, when present, forms an outline to the colour. Rings may be left upon the surface of ware by the thrower, and may be carved by the artist. Etching and carving as described are generally applied to fine stoneware. This ware may also be decorated by the following processes:—By dipping a dark ware in a light-coloured clay slip, and etching through the latter so as to disclose the dark background; by modelling the borders of patterns out of strips of clay laid upon the vessel whilst still plastic; by painting upon a dark body with light-coloured clay pigments, in certain cases, using a vitrifiable pigment, so as to become semi-transparent, and to disclose the background; by applying to the surface of ware, dots, rosettes, gems, or patterns, previously moulded in plaster moulds, or modelled ornaments in the form of dragons or faces. The decoration known as *pâte sur pâte*, and generally applied upon china or porcelain, and covered with glaze, is produced by modelling in a porcelainous paste spread upon the surface of the ware. The surface of the ware is generally of a dull-grey or green colour, applied to the ware by dipping in a coloured slip or glaze. The colour shows through the thinner parts of the sculptured ornament, the paste employed being of a semi-vitreous character. The bas-reliefs applied to Wedgwood's jasper ware are formed in moulds, and are made to adhere to the unbaked ware, by means of liquid slip. The ware, if it be not already coloured in its substance, is generally dipped in a coloured slip, before the application of the bas-reliefs. Certain wares are decorated with flowers and delicate sprays of foliage, to the manufacture of which, reference has already been made.

The glaze is a simple form of applied decoration. It is, as has already been stated, a glass built up of two or more silicates. The normal felspathic glaze consists of sodic or potassic and aluminic silicates; salt glaze, of sodic and aluminic silicates; lead glazes are mixtures of plumbic with aluminic silicate, and small quantities of sodic and potassic silicates. There are also glazes containing zincic silicate, and ferric silicate, and, in some cases, one silicate is replaced by a borate. Glazes may be rendered white and opaque by the addition of an infusible excess of stannic and arsenic oxides, and may be coloured by metallic oxides, in the same manner as glasses. Glazes are applied by dipping, and by volatilization. The difficulty in preparing a glaze is the regulation of the mixture, so that the contraction of the glaze after fusion shall not be unequal to that of the body to which it is applied.

The well-known decorative effect of "crackle-glaze" is obtained by an adjusted disagreement between the body and the glaze. If the disagreement be allowed to go too far, the glaze chips away from the body. The requirements of a glaze are (1) agreement with body, (2) power of resisting solution and corrosion, (3) purity of colour, (4) power of developing applied colours. The felspathic and sodic silicate glazes are the most durable; the plumbic silicate glaze is liable to gradual decay, which is indicated by the appearance of a beautiful iridescent film. "Smears" and "flows" are glazes applied by volatilization. In the former process, the saggers are washed inside with a mixture of one or more of the following substances: salt, red-lead or litharge, potassic nitrate, potassic carbonate, and china stone. The ware, generally fine stone-ware, is exposed in these saggers, and receives a gloss by the deposition and combination of the volatilized mixture. The object of the use of "flows" is to soften or blur the outline of under-glaze painting or printing. Ammonic chloride, alum, and chalk, together with one or more of the materials used for "smears," are placed in small biscuit-cups in the saggers, together with the ware. The glass which is formed by the deposition of the mixture on the ware partially dissolves the colouring oxide, and softens the general effect. Plumbic silicate glazes are coloured by metallic oxides, and are used for colouring ware. In this way, imitation "crown" ware is often manufactured. A mottled or marbled surface is sometimes produced on ware by instilling differently coloured glazes from a vessel containing several chambers communicating with a composite neck. Opaque glazes or enamels are used to conceal a coloured body. Majolica is generally made of common fire-clay or marl, and is coated with opaque white enamels, upon which, whilst still moist, coloured enamel decoration is applied. Limoges ware is a clay body decorated by the aid of coloured enamels.

In Cloissonné ware, the outline is marked out by metallic threads soldered to a metallic body, and the interstices are filled up with enamels. Imitation Cloissonné is produced by painting on a white clay body with coloured enamels, or by forming a raised outline by painting with a mixture of iron and copper dust, hardening the same by fire, and filling in with colour. Palissy ware has a white or coloured body, covered with transparent coloured glazes. Bristol ware is coloured by coloured felspathic glazes. A curious lustrous or glistening effect may be caused by applying coarsely-powdered mica to the surface of ware. Genuine lustre or iridescence is produced by the irregularity of a glazed surface, caused either by decay, or by the adhesion of an almost imperceptible metallic film. Bismuth, gold, silver, copper, zinc, iron, and platinum are used for this purpose. The metallic salt is generally mixed with some strong reducing agent, and applied to the ware as a paint. The ware is then fired in a reducing atmosphere, the salt is reduced, and the metal is fixed upon the glaze of the ware by heat.

For Brianchon's lustre, which is similar to that used at Belleek and Worcester, a mixture is used of bismuth nitrate, resin, and essence of lavender. If ferric or uranic nitrate be added to this mixture, the glaze of the ware will be tinted by the ferric or uranic oxide, and the effect of the lustre will be heightened. Instead of applying the reducing agent together with the metallic salt, a reducing vapour may be directed upon a pigment rich in copper, silver, or other metals, with similar results. The red lustre of Gubbio ware is due to the action of smoke upon cupreous oxide; it is usually applied to a coloured body. Gilding and silvering are performed by fixing metallic gold and platinum upon glazed ware by partially fusing the glaze in small muffles or kilns adapted to the purpose. The metals may be used in leaf, as amalgams, in powder, or as precipitates from solutions. When used as an amalgam or in powder, a small quantity of flux is added.

Gold may be precipitated from solution by ferrous sulphate; the precipitate, after washing and drying, is mixed with bismuth oxide, and mixed as a pigment with thickened oil of turpentine. Platinum sponge may be similarly treated. A bright silver may be obtained by using as a pigment a mixture of platinic chloride and essence of lavender. The gold powder and amalgams require prolonged and careful grinding before they are fitted for use as pigments.

The metal, after firing, is generally dull, and if a bright gold is needed, it must be burnished by rubbing over with an agate or bloodstone. "Chasing" is marking with a burnisher a bright pattern upon a dull unburnished ground. The gold pigment may be applied over raised bosses of paste, or over depressed patterns eaten into the glaze by hydrofluoric acid. Patterns may be painted with the brush, and lines may be accurately described upon the edge or sides of ware by applying the brush, and causing the vessel to turn upon the operator's hand, or upon a horizontally revolving wheel. Patterns may also be stencilled on the ware with charcoal, and gilded over.

By mixing gold with silver in various proportions, and using the mixtures as pigments, a large number of tinted golds and bronzes may be obtained. Coloured decoration upon the surface of ware is produced by metallic oxides dissolved in or covered by the glaze, or by the application of opaque coloured glasses. Metallic oxides applied on the body of ware and under the glaze, as well as those mixed with the glaze, obtain the glass necessary for their development from the glaze. Metallic oxides applied on the glaze are used in the form of coloured glasses or enamels. The latter may always be detected by the touch, as they are raised above the level of the glaze. Colours produced by certain oxides are developed by special media, and certain colours are able to withstand a much higher temperature than others. To the latter class, belong the oxides of cobalt, chromium, iron, titanium, and uranium; these are adapted to English underglaze decoration; but the blue produced by cobaltic oxide is the only colour able to resist the intense heat required to fuse the glaze of Oriental and Continental hard porcelains.

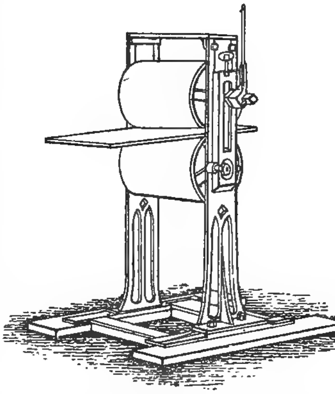
Zincic oxide tends to brighten a large number of colours; others cannot be developed without the addition of stannic or sodic oxides; and others, especially the pinks produced by gold, deteriorate in the presence of plumbic oxide. The subjoined oxides when mixed with a glass give the following results:—Ferric oxide, yellow; ferrous oxide, green; manganic oxide with sodic oxide, violet, passing to grey and black; chromic oxide, yellow; a trace of chromic oxide with stannic oxide, pink; pink, crimson, brown, black, and green are obtained for underglaze printing colours from various combinations of chromic oxides; all kinds of overglaze greens, and some yellows, are due to the same oxide; cobaltic oxide, blue, deepening to black, and brightened by zincic oxide, but injured by the presence of manganese or nickel as impurities; cupric oxide with sodic oxide, turquoise-blue, passing to green; cupreous oxide, red; auric oxide with stannic oxide, pink to purple; uranic oxide, yellow to orange; titanic oxide, yellow; antimonic oxide, yellow; plumbic oxide, pale-yellow; iridic oxide, black or opacity. All intermediate tints may be obtained by mixing the oxides.

Certain colours cannot withstand a high temperature, and other colours vary in tint with variations of temperature. Upon this fact, pyrometrical tests for burning-in coloured glasses and enamels are based. The heat of a muffle is ascertained by withdrawing from time to time a piece of china or porcelain marked with a glaze containing auric and stannic oxides. As the temperature rises, the tint changes from brown to brick-red, from brick-red to rose, from rose to purple, from purple to violet, from violet to pale-rose, and from pale-rose to a colourless stain. Wedgwood's pyrometer, which has been sometimes used for the same purpose, is based upon the regular contraction under the influence of heat of an unburnt clay mixture of known composition. Small cylinders of this clay mixture are expressed through a gauge, and after being dried, but before being placed in the kiln or muffle, are tested in a gradually tapering groove cut in copper or gun-metal. They are then placed in the muffle, and withdrawn when the temperature is to be determined. The temperature can be roughly estimated according to the position in the groove to which the contracted cylinder can be advanced, by reference to a scale determined by previous experiment.

Underglaze coloured decoration may be placed upon biscuit ware by the brush, or by a process of transfer printing. Only those oxides can be used for producing colour which are sufficiently stable to resist the heat of the glaze-kiln, namely those of chromium and cobalt. The pattern to be transferred is etched upon copper plates with steel gravers. When in use, the plates are kept warm by placing them on the top of a covered stove heated by steam, gas, or coal. The printing medium containing the colouring oxide is made up of a mixture of thickened linseed-oil, rosin, tar, and other ingredients, and is kept in a semi-liquid glutinous condition by exposure to heat. The ink is applied to the plate, and all the superfluity is dexterously removed by a scraper. A sheet of unsized linen tissue-paper, saturated with soft soap and well damped, is next spread upon the plate, and passed through the printing-machine.

The printing-machine, Fig. 1161, consists of an iron framework supporting two rollers, the upper one of which is partly wrapped with thick flannel. Between the two rollers, is a planed iron table, upon which, the copper plate is placed. By depressing the handle, the upper roller revolves, and causes the table to carry the plate between the two rollers. The resultant pressure transfers the ink from the copper plate to the paper. The printed paper is removed from the plate, and the margins are cut away. The paper pattern is applied to the absorptive surface of the biscuit ware, and is rubbed over with a roll of flannel. The ware is then placed in water, the paper is removed, and the pattern is found to be accurately printed. The printed ware is now dried, placed upon shelves in a kiln, and exposed to a red heat, in order to burn off the oily ingredients with which the metallic oxide was mixed. If the oily matter be not removed, the parts of the ware so covered will be non-absorptive, and unable to receive the glaze. After the ware has been gradually cooled, it is ready for dipping in the liquid glaze. By this process, outlines to be filled in by hand-painting, or patterns in one tint, can be printed. In order to print different shades of colour, a process known as "block-printing" must be adopted. In printing a leaf by this process, the different colours of the shadow, fibre, and ground are successively applied by separate plates upon the same paper, but care is taken that no two colours shall overlap. The pattern is transferred to the ware in the same manner as already described. The highest form of coloured decoration upon the glaze is hand-painting. Transparent coloured glasses and opaque enamels are used by the artist in the same manner as ordinary pigments, with the exception

1161.



that all have to be fired by heat, and allowance must be made for the changes in tint which the firing may produce. So great skill has lately been devoted to the preparation of these colours, that almost every known tint may be satisfactorily represented.

Raised effects and ornaments in relief may be executed in colour by modelling with a clay paste upon the surface of the ware, exposing to heat, and then painting with coloured enamels. Photography has not as yet been employed directly as a decorative process. There are two mechanical processes, in addition to ordinary printing, for producing coloured decoration upon the glaze, namely "ground laying" and "bat printing." The first is employed when an even coloured surface is required. The parts to remain white are painted by hand with a mixture of potassic carbonate and some adhesive vehicle, and the whole is then coated with oil. The coloured glass, or mixture of metallic oxide and flux in an exceedingly fine powder, is dusted over the whole surface, and adheres to the oil. The ware is then dipped into water, and the alkaline stencil reacts with the oil immediately in contact with it, causes it to saponify and peel off, carrying the colour with it, and leaving the space white. The ware is then dried and fired. "Bat printing" is used when exceedingly sharp outlines are required, as for instance for crests and monograms. The pattern is very finely etched on a copper plate, to which oil is applied, but almost entirely removed by friction from the operator's palm. Films of gelatine or glue are applied to the copper plate, and absorb the residue of the oil remaining in the lines of the engraving. The gelatine is applied to the ware, and transfers the pattern in oil to its surface. Powdered enamel is dusted on, and adheres to the lines printed in oil by the gelatine film. Printing may be executed on the glaze in the same manner as on biscuit, by incorporating a flux with the ink, and moistening the paper with essence of turpentine before its removal; or by removing the paper by heat, and dusting an enamel colour upon the adhesive outline which remains. In the latter case, the ink contains no colouring oxide, but is only an adhesive mixture. The construction of small mills, for the reduction of gold and other colouring ingredients to the state of fineness required for painting or printing, is of considerable importance. The following are descriptions of two which are considered serviceable. In one, a number of glass "mullers" fixed in a frame, to which a horizontal eccentric motion is communicated, press by means of springs upon a slowly revolving glass table. In the second, a single oval glass muller moves over a 2-ft. ground-glass slab, which is caused to revolve in an opposite direction to the muller. The motion of both is so arranged that the muller shall successively pass over the entire surface of slab. The muller is grooved on its base, to prevent suction, and carries a scraper, which directs the substance to be ground between the grinding surfaces.

The author desires to express his acknowledgments for special assistance rendered by the following well-known practical authorities:—T. Minton, C. Wedgwood, R. W. Binns, E. Stiff, Copeland, L. Arnoux, Abrahams, Brown, Westhead & Moore, Boulton, and A. Peto.

Bibliography.—A. Beckwith, 'Pottery' (New York: 1872); P. Bonneville and A. & L. Jaunez, 'Les Arts et les Produits Céramiques' (Paris: 1873); 'Modern Pottery Machinery' (London: 1876); 'Artizans' Reports on the Paris Exhibition' (London: 1878). H. J. P.

(See Clay; Glass).

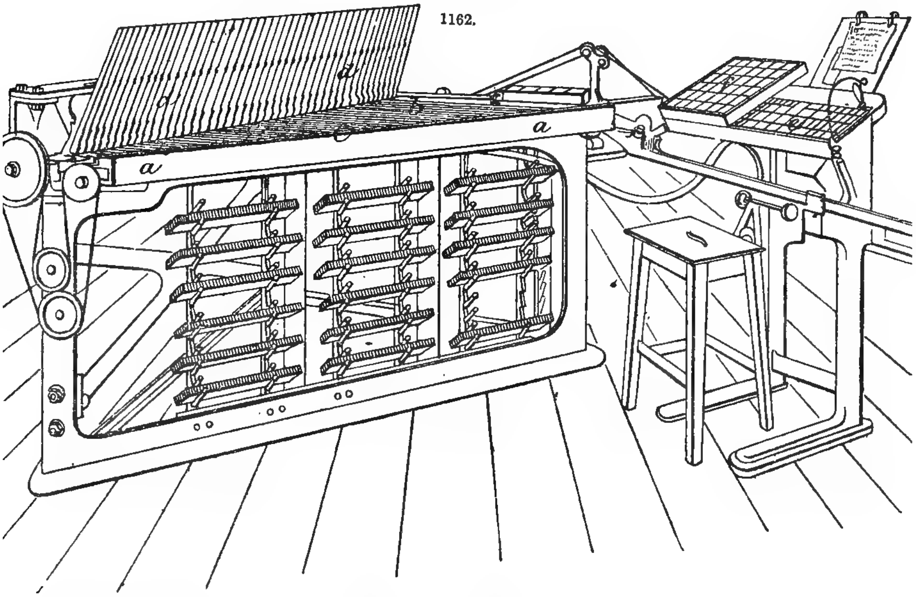
PRINTING and ENGRAVING (Fr., *Imprimerie et Gravure*; Ger., *Buchdruckerkunst und Stecherei*).

In the present article, the terms "printing" and "engraving" will be extended to embrace the following subjects:—Letter-press printing; printing in colours, and chromo-lithography; type-writing; autographic processes (manifold writers); engraving on wood, copper, steel, stone, and zinc; photographic processes (e.g. heliotype, Woodbury-type, Dallas-type, &c., &c.).

Letter-press Printing.—So little change has taken place of late years in the ordinary routine of letter-press printing, that there is no ground for an exhaustive essay on the subject. Progress is to be noted exclusively in the perfection of machinery for accomplishing the various objects, and to this branch, attention will be confined. It may be conveniently divided into four sections—composing-machines, printing-presses, finishing-machines, and cutting-machines.

Composing-machines.—One of the most remarkable inventions in connection with printing in modern times is the Clowes composing-machine, shown in Fig. 1162. It is the invention of John Hooker, a compositor in the employ of Wm. Clowes & Sons, Limited, of London and Beccles, and is in a certain degree based upon Mitchell's composing-machine exhibited in 1862. The machine is triangular, the sides measuring 5 ft., 5 ft., and 7 ft., the base forming the front. The table *a* is about 3 ft. above the floor; over it, travel a number (48) of endless tapes *b*, from the back towards a collecting-tape *c* passing from left to right. Over each of the tapes *b*, is a trough *d* filled with types lying on their sides, feet foremost. At the bottom of each trough *d*, is a little stop, on which the types rest; and just above it, on one side, is a knife or striker in communication with an armature. Electricity is provided by a couple of Grove's cells, or otherwise, and a series of wires connects the electro-magnet of each armature with the "setting-board," to be presently described. When the electric circuit is complete, the armature is attracted to its electro-magnet, and the striker pushes the lowermost type out of the trough upon the tape *b* immediately below it, by which it is conveyed to the collecting-tape *c*. The tapes *b* are driven by power at the rate of 7 in. a second, and the tape *c* at 21½ in.; the relative positions and speeds of the tapes *b* and *c* are so adjusted that each type shall unerringly assume the position corresponding to the order required by the matter to be printed. The setting-board *e* is placed in a convenient position for the compositor. It is divided into a series of copper discs describing the form of the receptacles of an ordinary lower case; each disc is connected by a wire with the electro-magnet of the letter indicated, while a second wire from the opposite pole of the battery terminates in a copper stylus, which is held by the compositor. Composition is effected by tapping with the stylus upon each disc in succession, according to the letters required; and as contact with any portion of a disc suffices to establish the circuit and bring down a type, while the area of the setting-board is only about 12 in. by 6 in., the process is exceedingly rapid. The setting-board does not embrace every letter and sign; those of rare occurrence are omitted, and a supply of them is kept in a small case *f* at the compositor's left hand, so that he can readily select them and get them into place by means of a little spout provided for the purpose over a spare tape. The composed matter forms one continuous line, which is removed at intervals and justified. Into this line, only one type can enter at a time; in case of any derangement or obstruction, a lever breaks the connection, and the machine is arrested till it has been rectified. The effective capacity of this machine amounts to 10,000 types hourly set up in page form, employing four lads setting, justifying, and replenishing the type-troughs. Only one fount can be used at a time, but the machine is adapted to take 4 or 5 different founts by simply exchanging the types.

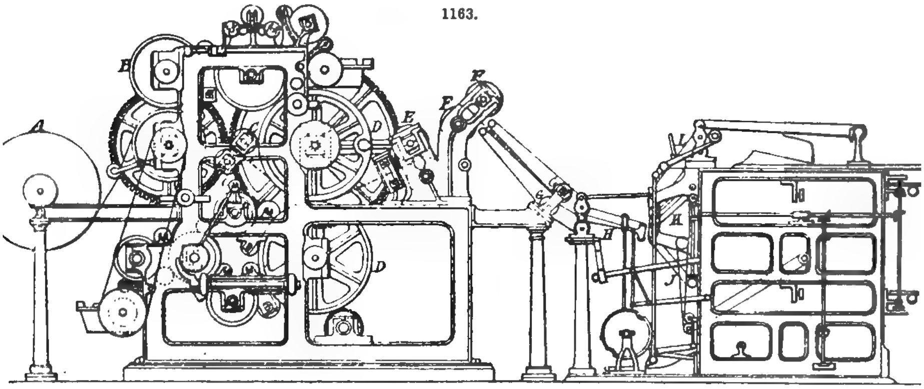
1162.



Printing-Presses.—In the article "Press" in 'Spons' Dictionary of Engineering,' pp. 2660–2670, will be found detailed descriptions and illustrations of the most notable improvements in printing-presses up to that date. Since then, the following has been introduced:—

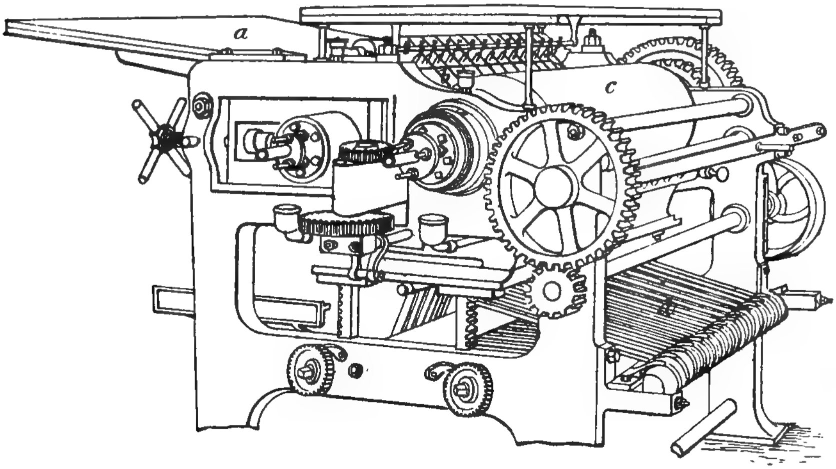
Ingram's.—This is a web rotary machine, invented for printing illustrated newspapers, and used for the *Illustrated London News* and other papers issued from the same office. It is the invention of W. J. Ingram, and is made by Middleton & Co., Loman Street, Southwark. It is illustrated in section in Fig. 1163: A is the roll of paper, containing a length of 2–3 miles; B, the type- and impression-cylinders for printing the inner forme, or type-side of the paper; C, calendering- or smoothing-rollers, to remove the indentations produced by the impression of B, so that a smooth surface is preserved to receive the outer forme, or illustrated side of the paper, which is printed by D; E, cylinders, one provided with a saw-toothed knife, and the other with a corresponding indentation, to perforate the paper between each impression; F, rollers for holding the paper securely, to resist the effect of G, which are called snatching-rollers, and, being driven at a rather higher surface-speed than the holding-rollers, snatch or break the paper at the places where it has been perforated, and form it into separate sheets. As it is found that machinery for folding newspapers works much better at a moderate speed, in this case, it has been arranged in duplicate, so that each folder only works at half the speed of the printing-machine. The vibrating arm H delivers the sheets alternately to K and J, which are carrying-tapes leading to the two folding-machines. If the sheets are wanted unfolded, the arm H is moved to its highest position, and there fixed; it then delivers the sheets to the roller L, and, by means of a blast of air and a flier, they are laid in a pile on a table provided for them. This change can be made without stopping the machine. The dotted line from A to L indicates the course of the paper through the machine. The effective capacity is 6500 copies printed and folded per hour. This machine has proved so superior for all illustrated work that it is coming into use among first-class general printers.

1163.



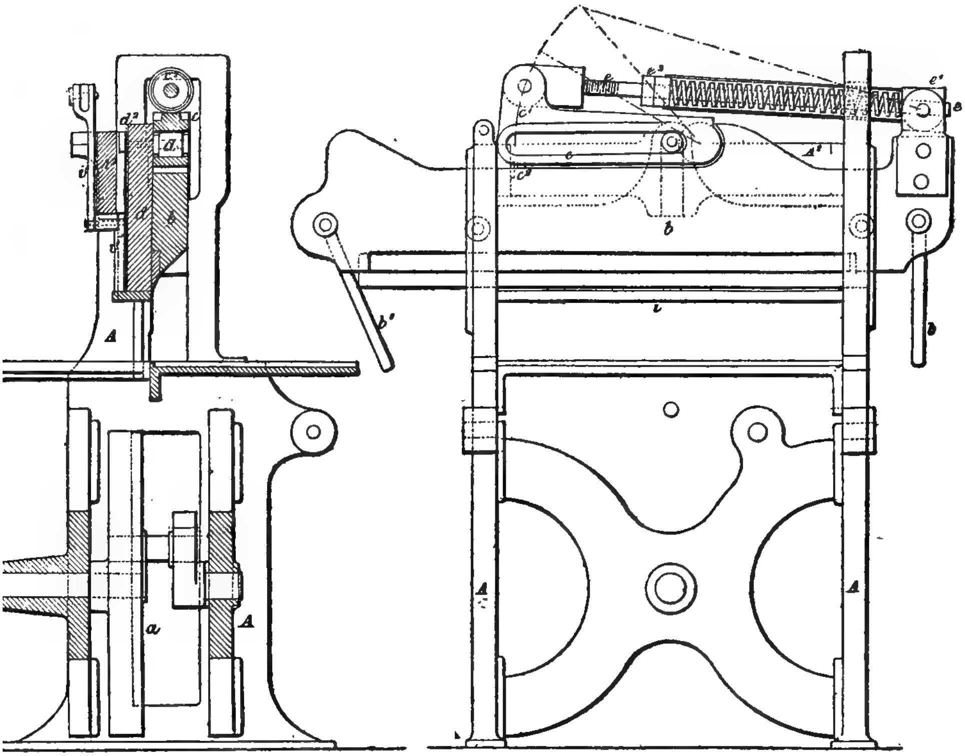
Finishing-machines.—Gill's rolling- and finishing-machine, made by Furnival & Co., Manchester, is in almost universal use among English printers. The latest improved form is shown in Fig. 1164. The printed sheets are fed from the table *a* by means of endless carrying-tapes *b*, between two rolls *c*, which are hollow, so as to receive steam, when it is desired to hot-roll the paper. The passage between the rolls gives a polished surface to each side of the paper. The finished sheets are delivered by another endless tape *d* to a table. An indiarubber "doctor" or scraper cleanses the faces of the rolls from any possible adhesion of ink after each sheet has passed through.

1164.



Cutting-machines.—One of the most improved "guillotines," or paper-cutting machines is that invented by Salmon & Capper, Manchester, and shown in Figs. 1165–6: A is the side frames; *a*, wheel with crank for giving motion to the knife-bar; *b*, knife-bar, with diagonal slots, to give the lateral movement as it descends; *b′*, parts of the rods between the knife-bar and beam; *c*, slotted link, jointed to the upper edge of *b*; *d*, clamping-plate, bearing a bowl *d′* upon a stud, and a second bowl d^2 at the back. One end of the screwed rod *e* is jointed to a projection *c′* from the link *c*, the other end sliding through a hole in a swivel-piece *e'*, having pivots carried by brackets bolted to the end of the knife-bar. A steel spring e^2 is placed upon the screwed bar, abutting against the swivel-piece at one end, and against screw-nuts e^3 at the other. When the knife-bar *b* descends, and the clamp *d* comes upon the paper to be cut, its descent is arrested, and as the knife-bar continues its downward movement, the bowl *d'* in the clamp remains stationary, acts upon the slotted link *c*, and causes it to assume a greater or less angle, according to the thickness of the paper being cut.

1165. 1166.



Printing in Colours, and Chromo-lithography.—Printing in colours as usually effected requires a separate impression to be taken for each colour, as great difficulty is experienced in combining the pigments for a polychrome print so as to complete the operation by one impression, on account of their varying densities and consistencies. W. G. White claims to have overcome the obstacle, and to have developed a process which is said to be in use on an extensive scale in Paris. His method, so far as divulged, is as follows. The prepared pigment chosen for the ground of the design is first run into a mould, so as to form a solid block about 3 in. thick. The pattern is traced with a steel point upon a sheet of "artificial talc," made from a mixture of collodion and oil, and this is pressed upon the block, so as to leave an impression of the lines upon its surface. The pattern is then cut out of the block by a sharp steel knife mounted on the end of an articulated parallelogram, so as to be maintained in a vertical position, while at the same time having a perfectly free horizontal motion. The various pigments forming the designs are then poured into the spaces cut out, a kind of mould being formed temporarily by a portion of the ground colour, supplemented by strips of wood soaked in water. The paint is poured in hot and liquid, and, as soon as it has cooled, another is added, and so on, until the whole design is finished, thus forming a complete mosaic. In the case of a large subject, various portions of the block may be executed by different operators at once, and then joined together; the method is also being tried of cutting out the whole pattern in wood or metal, by means of a band-saw, and then forcing the die so formed into the block of ground colour, so as to stamp out the colour therefrom. The mosaic, or "type," as it is called, is put into a powerful press, resembling that used by lithographers, and is first shaved by a heavy steel knife, so as to render the surface perfectly even and smooth. The material to be printed upon is then laid face downwards on the slightly moistened block, and a series of rollers are passed over it once or twice, when the impression is found to have completely penetrated its substance.

The print is exposed for a few seconds to the heat of a hot plate, for driving off the solvents employed, and perhaps fixing the colours, which are printed so permanently as to withstand exposure to the sun, and when a piece of velvet printed in this manner was boiled for 8 hours in strong potash solution, the colour did not entirely disappear. Water-colour drawings and oil-paintings may be reproduced by this process, so as to present the appearance of chromo-lithographs and oleographs respectively. But it is stated to have a far more extended application, in printing upon textile fabrics the designs of Gobelins and Arbusson tapestry, to form curtains, *portières*, &c. The range of materials capable of being treated appears to be extensive, as the same design has been reproduced upon fine silk and the coarsest jute sacking, both impressions, it is said, presenting all the necessary sharpness of outline.

Bacon's multicolour printing-press, shown at the recent fair of the American Institute, will print in 8 colours at a single impression. This is attained by a special arrangement of the inking-table, which, instead of being in a single piece, is composed of a number of narrow cast-iron plates held in a frame. These plates are formed of four distinct parts, and are wide in the centre and taper conically toward the extremities. This mode of construction allows them to move easily on each side at every revolution of the table, and has nearly the effect of an articulated joint. The end piece near the ink-trough is stationary. The various coloured inks are placed in the ink-trough, which is divided into cells by metallic partitions. Directly over the trough, is an iron frame carrying a set of screws and nuts. By tightening these screws, which are placed over the metallic partitions, the inks as they flow beneath are prevented from mixing. The inking-rollers, instead of being fixed at a certain angle relative to the table, are arranged so as to run perfectly straight, the distribution being effected by the plates. The inks are spread on the multiple table in the usual way. As a consequence of the motion of the articulated joint, the inking-table is caused to move slightly at every revolution of the table, and the ink is thus as well distributed as if several rollers were used. The movable plates which constitute the inking-table are of different widths, so that the uppermost or the lowest line in a page can be printed in a colour selected beforehand. Motion is communicated to the movable plates by a small lever which hangs under the table, and which rests on a small vertical iron plate affixed to a cross-stay of the machine.

Chromo-lithography varies from simple colour work to tinted lithography and oleography. All coloured lithographs require a separate stone for each colour; hence to ensure the correct position of each impression, it is necessary to have a "key-stone," on which the limits of each colour are distinctly and accurately laid down, the key-stone itself being omitted in the printing, except for common work. The "set-off" or "faint," which is the "trace" produced by an impression from the key-stone in an ordinary press (as described under Engraving on Stone), must have the exact dimensions of the original, to ensure which, it is best to use good, stout, cream-wove note-paper, taking care that it is dry and well rolled, and the key-stone quite dry, and performing the operation without delay. The impression may be dusted over with red chalk, and snapped with the finger-nail to remove excess, and may then be laid upon another stone, and passed through a press to communicate the image. As to the order in which the colours should be printed, this depends somewhat upon the effect desired, but the general rules are that a dust-colour should always precede (not follow), and that transparent colours should succeed opaque ones, the common order being (1) dust-colours, (2) blues, (3) reds, (4) yellows, (5) outline- and finishing-colours.

"Registering," or adjusting an already-printed sheet to the stone for further additions, is a delicate operation, which may be performed in three separate ways. The most simple is the "lay." The paper should possess well-defined corners and edges, and its size is determined before making a set-off. This done, a "lay" corresponding to the edge of the paper is made on the stone, and the subject is thus brought into position on the sheet, the lay being then drawn in fine lines of lithographic ink, so as to print on the set-offs throughout. A set-off is made for each colour, and the lay-mark is permanent. When printing a light colour, the lay-mark may be rendered permanent by covering the place with gum, and making scratches through it when dry to coincide with the marks replaced, marking with common writing-ink, and washing the gum away when dry. The second method is by needles, taking advantage of permanent lines in the picture, or making tiny marks at the edges. The needles consist of slips of wood or cane 1½ in. long and ¼ in. thick, penetrated by a sewing-needle so that about 1 in. projects. The set-off on the stone is perforated by the needles at two opposite corners, and the sheet is pricked at the corresponding corners. The needles are passed through the sheet from the back, and the sheet is thus dropped into its place on the stone, while the operator withdraws the needles and his fingers. This method is simple when the paper exceeds the size of the stone. A third plan differs from the last only in having the needles fixed in a lath. These three methods (particularly the two first), though in very general use, present some objections, the removal of which is sought to be accomplished by two more recent plans. The first of these consists in letting leaden plugs about $\frac{5}{8}$ in. long and ¼ in. diameter into the stone for the reception of fixed wire pegs at the centre of each end of the stone, which are made to project about $\frac{1}{16}$ in., and to puncture each set-off. When the stone much exceeds the size of the paper, one peg may be soldered to a strip of brass tinned at the back, and fixed to the stone by blowing on a piece of shellac. The second improved method is to fasten two brass strips, shaped respectively like the letters | L, to the key-stone by means of shellac, and placing identical marks on each stone. Registering-machines have been devised, but are not in general use.

The paper for colour-printing must be thoroughly stretched by rolling after it comes into the lithographer's hands. The temperature and degree of moisture of the room must be kept as constant as possible, to prevent stretching and shrinking in the paper. When printing on damp paper, it must be kept damp by covering it, and placing it out of draughts. The drying of the ink after each impression is best done in a special apartment at a sufficiently high temperature; in this case, the paper should be similarly dried before making the first impression. The surface of the stone used is polished when pen or brush is to be employed, but grained for chalk and tints, the graining being coarser for colour than for black. The "setting-off" of colours may be avoided by dusting the printed sheets with a powder of chalk, talc, or magnesia, but this is liable to deaden the colours.

The tints for imitating the light washes of colour in water-colour drawings and similar work, are produced in various ways, on the principle of covering the stone with a fatty substance in such a manner that it would roll up of full strength all over, except where part had been removed. When chalk is to be imitated in the tints, the stone must be coarse, but very sharp-grained, and the set-off must be made clearly visible throughout the operation. The set-off being made on the grained stone, the margin and high lights are stopped out with gum and acid, and the ground is laid. Should the set-off be too weak, an impression dusted with red chalk or vermilion may be registered upon it, and lightly pressed. The ground forming the tint must be hard enough to bear scraping without smearing, must roll up solidly after etching, and must be removable by solvents of fats. Of the several substances that may be used, preference is given to Brunswick-black and copal-varnish. The evenly laid ground is left to dry, and the lights are put in by the scraper and preserved by etching. In producing tints of various gradations, the ground must not be laid on with the roller, as in the preceding case, but by warming the stone, and applying "rubbing-in" ink till the grain is filled in, then removing the excess of ink by a piece of woollen. The whole subject of tints, and the pigments and driers employed to produce them, is one of great intricacy, and demands unusual care and experience. The best works on the subject will be found quoted in the bibliography at the end of this article.

Mention may here be made of a machine and process designed by Arthur Rigg for doing away with the necessity for having a separate stone for each colour, at least in the case of such work as map-outlines. These outlines are laid down on a thin sheet of brass, and the various colours, placed side by side in cakes in an iron frame, are cut apart by scissors. Each piece of brass is then laid upon a cake of the required colour, and made to adhere to it, and the colour is cut to the exact form of the plate by a small wire-band saw. When all the pieces are furnished with colour, the whole is put together in the chase, and welded into homogeneity by warmth and pressure. The coloured ground-work being printed, an impression from the black "key-stone" is made on the top.

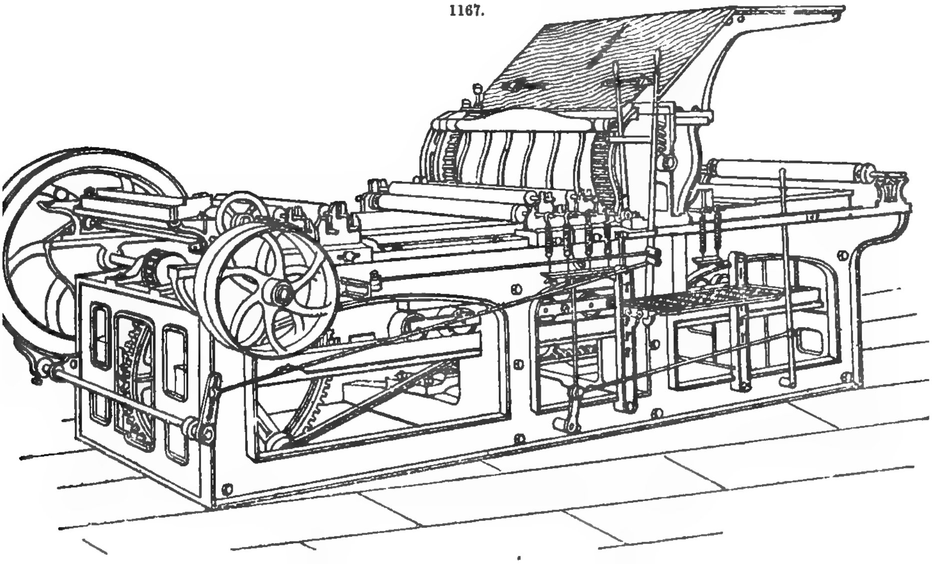
The chromo-lithographic machine made by G. Mann & Co., Leeds, and in most general use in this country, as well as largely on the Continent, is shown in Fig. 1167.

Type-writing.—During the last 25 years, a great number of machines have been introduced for writing by means of type-letters. The following are the most notable examples.

J. Pratt's (of Alabama) has the type fitted on the face of a small plate, about ¾ in. sq. This is supported vertically before a frame carrying the paper by an arrangement of levers capable of giving it both vertical and horizontal motion. The plate is thus shifted into any position, and any type required can be brought opposite the point where the impression is taken. As this is done, the same mechanism which moves the plate sets in motion a small hammer, which strikes the paper on the opposite side to the plate, and forces it against the type, thus producing an impression. When the carbon paper is used, several copies can be taken. In order to limit the number of keys required to operate the levers for shifting the type-plate, there is one set of keys for giving the vertical movements, and another for giving the horizontal movements. Thus, for each letter it is required to move two keys; but as each key of one set could be used with each key of the other set, a much smaller number of keys is necessary than if one key were requisite for every letter. It may make it appear clearer to say that the depression of one key brings into position the vertical line containing the type wanted, and the horizontal line containing the same type; consequently the intervention of the two lines, where the special letter needed is to be found, is brought into the proper place for the impression. The paper is carried in a small frame, traversed after each letter by a rachet-wheel and pall. At the end of a line, the frame is raised by a rack worked by a separate key, and at the same time thrown back to the proper side of the machine for commencing a fresh line.

Sir C. Wheatstone invented several type-writing machines. No. 1 is in its main features somewhat like Pratt's. The paper is held in a vertical frame sliding in guides across the machine, and the impression is produced by the blow of a small hammer on the type, the paper being interposed between the hammer and the type, and the type moved to its proper place each time. The differences, however, in the methods of mounting the types and actuating the mechanism are very great. The type is set in three rows on the periphery of a small wheel on a vertical spindle. Thus, by shifting the wheel up or down (in the direction of its axis) the line containing the letter required is brought to the proper point on a level with the hammer, and by rotating the wheel, the letter itself is brought round. Both these motions are effected by depressing the same key, there being a key corresponding to each letter on the type-wheel. The spindle of the type-wheel is rotated by a spring, which gives the traverse to the paper, and which therefore is wound up by drawing the frame back to its original position after the completion of each line. The depression of the key, acting through an arrangement of levers, raises the type-wheel to the required height, and, at the same time, sets free a catch, so that the wheel is turned round by the spring till it is caught by the second catch, the position of which corresponds with that of the letter required. The hammer is worked by an arrangement something like that used in the piano, and so mounted that the blow is given after the type has been brought into position. The action is somewhat heavy, and unless the key is depressed sharply, and with a little jerk, the hammer is not operated, and consequently no impression results. But the machine as it stands is capable of very satisfactory work. The other three forms are on a different principle, but much alike among themselves. The types are set each on the end of a small lever, and these levers are arranged side by side in the form of a quadrant, each lever being pivoted freely. The whole set of levers is connected with a sliding plate, by shifting which to the right or left a suitable distance, any one of the levers is brought over the point where the impression is to be taken. The type being thus held over the proper spot, a small hammer strikes it down on the paper below. The sliding plate extends along the front of the instrument parallel with the row of keys, which resemble piano-keys. It has in it a number of slots, into each of which a pin slides, the arrangement being such that each pin and slot moves the plate a certain distance, differing from that to which any other pin moves it, and corresponding with the distance necessary to bring the letter required into action. Each pin is actuated by one of the keys of the key-board. Thus, by depressing the proper key, any required letter is brought under the hammer. The types are charged with ink by being brought against an inking-pad at each side, as they move. The paper on which the impression is to be received is fitted on a cylinder, which is revolved continuously. The writing is consequently carried round and round the cylinder. As soon as it reaches the spot where it began, the cylinder is shifted longitudinally, so that a fresh line is commenced. There seems no reason why a reciprocating plate, with suitable means for shifting it at the end of the line, should not be substituted for the obviously inconvenient cylinder. With this improvement, perhaps, a machine of this character might be brought into practical use. In its present form, the arrangement which prevents the use of paper of any other than a certain size and shape is a considerable drawback.

1167.



In R. M. Hansen's "writing ball," the chief peculiarity is that the keys are all arranged over a semi-spherical surface, which, to a certain extent, conforms to the shape of the hands. The keys are formed of pistons, set as radii of the sphere, so that each key strikes at the same spot. The keys are depressed directly by the fingers, and are raised by small springs. The paper (carbonized and white) is carried either by a cylinder or a plate under the "ball." In the original machine, the paper was moved continuously by clockwork, or a small electrical motor; but in the more recent forms, the paper is traversed by a movement derived from the key which is depressed. This slightly depresses the bed on which the paper is supported, and by suitable apparatus, this movement is caused to carry the paper forward a single space. It is stated that with practice, great rapidity can be attained by the machine, and the direct action of the keys on the paper enables considerable force to be applied, and consequently a large number of "manifolded" copies to be obtained.

The "Remington" machine has in front a key-board holding the letters and numerals; on pressing any one of the keys, a small lever bearing the corresponding letter is made to strike against a ribbon saturated with prepared ink (presumably glycerine and an aniline violet), over which, the paper is held on a roller. Each letter strikes at the same spot, but the roller and paper move one space forward after each letter, so that each letter falls into its proper place. The mechanism is very simple, the levers carrying the letters being actuated by an arrangement similar to that of a piano, and strung on a circular wire, so that they all strike into the centre of the circle. As soon as a line is finished, the roller is taken back to its original position by a treadle, and is at the same time revolved one tooth of a rachet-wheel, so as to bring a fresh line under operation. The type is all "small capitals," and the printing is regular and even. It is said to be easy to attain twice the speed of ordinary writing. The machine will "manifold" about 20 legible copies with carbon-paper.

In A. Barlow's machine, a vertical cylinder carries the types, and is raised or lowered to bring the required letter opposite the place on the paper where it is to be impressed. This raising or lowering is effected through the action of one key, which, being raised or lowered to a certain height, acts through suitable mechanism to raise or lower the type-cylinder likewise. The key is slotted with a number of slots corresponding to the number of letters; the finger being placed over the slot, and the key depressed, it descends until it reaches the level of a pin which enters the slot and is stopped by the finger. All the other pins pass freely through their slots.

The "Crandall" type-writer (Caldwell, New York), is a small machine costing 10*l.*, weighing 9 lb., mechanical and automatic in action, self-contained, and manipulated by 27 keys. It writes capitals, small letters, script, numerals, and all the various stops and signs. The keys are grouped to facilitate the writing of oft-recurring small words. Each letter is written in front of the operator, and can be seen as soon as written; 60–70 words a minute can be written after short practice, and over 100 by experts. It manifolds readily. Circulars written by it go as "printed matter" by post.

Autographic Processes—Manifold Writers.—Perhaps the most simple and effective methods of obtaining a very limited number of copies of a document by one operation of writing are the ordinary pencil and carbon-paper, and the familiar copying-ink and tissue-paper. For obtaining a large number of copies, however, while too few for a lithographic press, several methods have been recently introduced.

In Zuccato's "papyrograph," a sheet of fine paper is saturated with a resinous varnish, and dried. On it, writing is made with an ink consisting of a strong solution of caustic soda, slightly coloured in order to be more obvious to the eye. The soda immediately attacks the resinous preparation of the paper, converting it into a soap. The sheet is floated on water, the written side being upwards; the water soon penetrates the softened parts, making the written lines stand up in bold relief as ridges of fluid. The paper is now removed from the surface of the water, and pressed between folds of blotting-paper, after which it is once more floated on the surface of the water, and again blotted off, in order to remove the remainder of the resin soap. The sheet thus prepared forms a stencil, of which the general ground is impervious to moisture, while the written lines, being denuded of varnish, are quite porous, and afford an easy passage to an aqueous liquid. In the early days of papyrograph printing, a pad, saturated with persulphate of iron, was placed at the back of the stencil, while the paper to be printed on was moistened with a solution of ferrocyanide of potassium. The iron salt being forced through the porous lines by a gentle pressure, reacted on the ferrocyanide; a blue impression was the result. It is now, however, found to be more convenient to print from the stencil by means of an aniline colour dissolved in glycerine, and the colouring power of this kind of ink is so great that dry paper may be used for receiving the impression. On a velvet pad which has been moistened with a solution of aniline blue in glycerine, is laid the paper stencil, this having been previously brushed over at the back with a little of the ink. It is now merely necessary to place sheets of paper on the upper face of the stencil, and to apply gentle pressure by means of an ordinary copying-press, in order to obtain copies rapidly and easily. The copies can be printed off more quickly by this process than by typography or lithography. About 600 copies can generally be taken from one stencil.

Another class of printing stencil is made by the mechanical perforation of suitable paper or tissue. Stencils perforated by a rapidly rising and falling needle-point, actuated by a treadle, have long been used for the printing of embroidery patterns. In such a case, powdered colour, mixed with resin, is dusted through the stencil, after which the device is fixed by the application of sufficient heat to soften the resin. Edison proposes to use such perforated stencils for ordinary autographic printing purposes, and replaces the complex treadle perforating-machine by a kind of pen, in which a needle-point is made to move rapidly up and down by means of a small electric motor attached to the instrument. When Edison's electric pen is connected with a battery of two elements, the needle rapidly passes in and out of the perforated point of the instrument. If written with on a piece of blank paper, the paper becomes perforated. The sheet of ink-proof paper having been written on with the electric pen, can be used as a printing stencil by merely laying it down on a sheet of white paper and passing an inking-roller over its back. The operation of printing is very rapid, so that many copies can be produced in a short time. Other perforating pens have followed in the wake of Edison's electric instrument, among which may be mentioned the "horograph," a very convenient and portable clockwork pen, manufactured by Newton, Wilson, & Co., of Cheapside. A pneumatic pen, in which the motive power is a stream of air supplied from a foot-bellows, has also been introduced into the market. A still more complex and expensive arrangement than either of the preceding, for producing perforated stencils, consists of an induction coil, capable of giving a sufficiently powerful spark to perforate the stencil-paper; and this spark is made to continually pass between a partially insulated metallic pen and a metallic plate, on which the stencil-paper is laid.

All these perforating arrangements have the disadvantages of being expensive, complex in construction, and liable to get out of order when used by unskilled persons, while the perpendicular position in which the mechanical perforating pens must be held, necessarily hampers the freedom of the writer. In a new perforating method recently introduced by Zuccato, the impervious stencil-paper is laid on a hardened steel plate, cut on the face like a fine file, and the writing is executed by means of a point or style of hardened steel. Under these circumstances, the teeth of the file-like plate perforate the paper wherever the point of the style exerts pressure, and a stencil eminently adapted for printing from is the result. This kind of printing is called "trypograph." A sheet of the prepared paper is laid on the file-like plate and written upon with the hardened steel pencil, the operation of writing being as easy as if a pencil were employed. By fixing the stencil on the frame of a desk-like press, placing a sheet of white paper underneath, and then pushing over the upper surface of the stencil an indiarubber scraper or squeegee charged with printing-ink, the ink passing through the perforation produces a copy of the original writing. As many as 6000 copies can be obtained from one stencil. Thin metallic plates are readily perforated by Zuccato's method, and calico receives the trypographic impression admirably.

Pumphrey's "collograph" depends on the fact that when a film of moist bichromated gelatine is brought into contact with ferrous salts, tannin, or certain other substances, the gelatine is so far altered as to acquire the property of attracting a fatty ink. Pumphrey supplies plates of slate or glass covered on one side with a thin film of gelatine, and these are prepared for use by being soaked in a weak solution of potassium bichromate, all excess of moisture being then removed by first wiping with a cloth, and afterwards rolling paper on the damp surface. A drawing or writing, which has been made with either an ordinary iron and gall-nut ink, or with a special ink, is transferred to the prepared plate, just as in the case of the transfer to zinc. The original being removed, the plate is inked by means of a roller, moistened by a sponge, in order to remove any trace of ink from the ground, and then printed from, much as if it were a lithographic stone, or a zincographic plate.

There are some methods, which are rather copying than printing processes, as they depend on the writing of an original with a very intense ink, and then dividing the ink, so as to obtain a number of feebler copies. The ordinary method of obtaining one or two reverse copies of a letter on thin paper is of this nature; but these processes, which are capable of yielding 30–60 fairly good copies, depend on the use of a solution of an aniline colour for writing. In the case of copying processes introduced by Pumphrey and Byford, the writing is executed with a strong solution of an aniline colour on thin, and tolerably hard, paper. The writing quite penetrates the thin paper, and on pressing a sheet of moistened paper against the back of the original, some of the aniline colour will set off on the damp paper, giving a direct copy of the original writing. In the same way, numerous copies may be produced; but processes of this kind cannot reproduce very fine lines with distinctness. A somewhat analogous arrangement for obtaining numerous copies is afforded by Waterlow's "multiplex copying portfolio" and its contents. The writing is done with the aniline ink, and a damp sheet of very soft and porous paper is pressed down on the writing. This soft paper absorbs a large proportion of the aniline ink, and itself forms a reversed printing-surface, capable of yielding a considerable number of direct copies to damp sheets of paper.

The just-described copying processes labour under the disadvantage of requiring the use of damp paper for receiving the impression; but this difficulty has been overcome in an arrangement which has been introduced under the names of "hectograph" and "chromograph," these differing from each other rather as regards detail than kind. The writing is executed on ordinary writing-paper with an aniline ink, and when the lines have dried, the original is transferred to the surface of a slab of soft gelatinous composition, analogous to that used for making printers' rollers, contact being established by a gentle rubbing with the hand. The original, after being allowed to remain in contact with the gelatine slab for about two minutes, is stripped off, leaving the greater part of the ink on the gelatine. To obtain the copies, it is now merely necessary to lay paper on the slab, and either rub down with the hand, or establish contact by means of a soft roller. The requisite number of copies having been obtained, or the colour on the lines being exhausted, the slab can be cleaned by means of a damp sponge, when it is again ready for use. A composition for making the slab may be prepared as follows:—1 lb. of gelatine is soaked in water until it becomes flaccid, after which it is melted, in a water-bath, with 6 lb. of common glycerine, the heat being maintained for a few hours so as to drive off all excess of water. The mixture is then poured out into zinc trays ½ in. deep, and allowed to set. The ink may be prepared by dissolving one part of aniline violet (blue shade) in a mixture of seven parts of water and one of alcohol. Letters written in coloured inks will give 150 copies, and in special black ink, 50 copies. The process is also known as the "Vienna multicopyist." Another composition for the slab consists of 130 parts water, 75 sulphate of baryta, 30 gelatine, 30 sugar, 180 glycerine.

Engraving. *On Wood.* The Block.—The best wood for the purposes of the engraver is box (see Timber), whether English, American, or Levantine; it should be light straw-yellow in colour, and free from black or white spots and red streaks, which indicate a soft wood. Small wood is generally pretty free from blemishes. The supply of good box-wood is by no means plentiful, and several other kinds of wood have been proposed or adopted as substitutes, the principal being sycamore and pear (much used for large coarse cuts, but too soft and irregular for fine work), *piacha*, persimmon, and American dog-wood; all these are described in the article on Timber. A substance deserving careful trial for this purpose is celluloid (see pp. 610–8), which might be obtained in sheets of any desired size. When wood is used, a large cut often necessitates the bolting together of several small ones. Wood blocks are about 1 in. high, and are then planed down to the exact height of type, and brought to a very smooth surface. They require keeping for some months to become seasoned.

Drawing on the Block.—Before any drawing can be made on the polished surface of the block, the latter must receive a slight wash. This is made with water and Chinese white, or very fine Bath-brick dust, or the scrapings of glazed cardboard; it is gently rubbed off when dry, leaving a surface on which the pencil will take. A tracing of the outline of the subject is made, and placed on the block with a piece of transfer-paper between, remembering that the picture will be reversed in printing. Every line is gone over with a sharp point. The outlines are then corrected and completed by a sharp-pointed H H H H pencil, the tints being afterwards filled in by a softer pencil, or thin washes of Indian-ink, to show the effects of light and shade. All washes must be used with such care as not to affect the wood by their moisture. The portions of the block not under immediate operation are kept covered with smooth, blue, glazed paper, to preserve them from injury, and reduce the glare from the lamp.

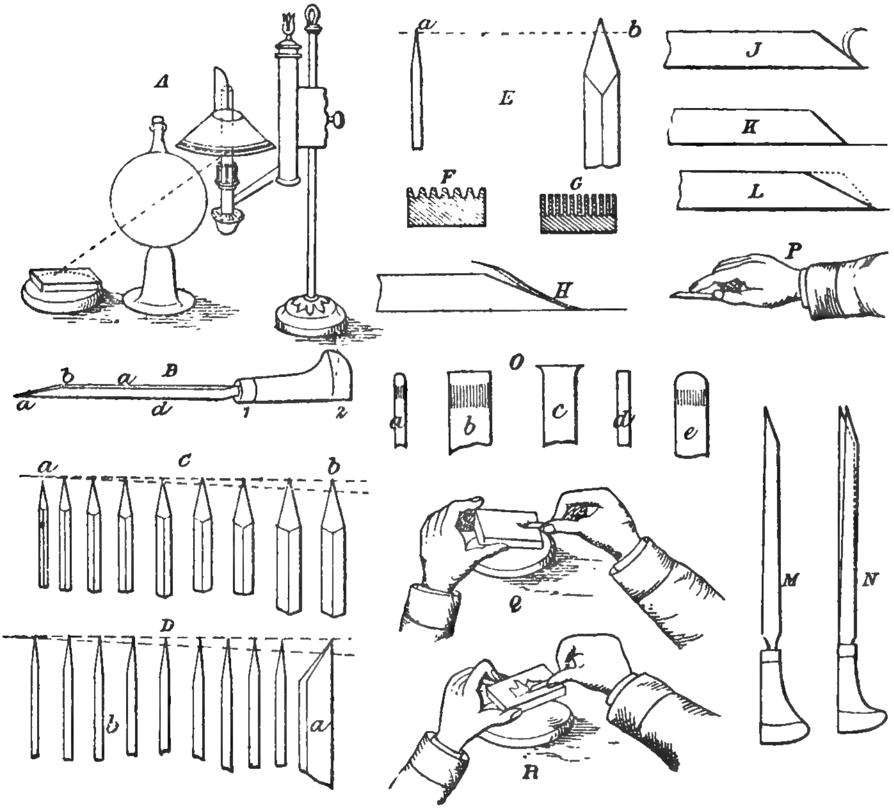
Proofing.—When the drawing is finished, a proof may be taken in the following manner, before blocking out the cut, that is, before the superfluous wood is cleared away:—Rub down a little printing-ink on a slab till it is fine and smooth; take some of this on a silk dabber, and carefully dab the block until sufficient ink is left upon the surface, without allowing any to sink below it. Lay a piece of India paper on the block, with about 2 in. margin all round; on this, place a thin smooth card; rub this over with the burnisher, taking care not to shift the card or paper.

The Lamp.—A clear and steady light, directed immediately upon the block to be cut, is a most important point, and in working by lamplight, it is necessary to protect the eyes from the heat and glare. The lamp shown at A, Fig. 1168, can be raised or lowered at pleasure, by sliding the bracket up or down the standard, it being fixed in the desired position by means of the small set-screw. A large globe of transparent glass, filled with clean water, placed between the lamp and the block, causes the light to fall directly upon the latter. The dotted line shows the direction of the light; by lowering the lamp, this light would take a more horizontal direction, thus enabling the engraver to work farther from the lamp. A shade over the eyes is occasionally used as a protection from the light of the lamp.

The Tools.—The tools consist of gravers, tint-tools, gouges or scoopers, flat-tools or chisels, and a sharp-edged scraper, something like a copper-plate engraver's burnisher, which is used for lowering the block. Of each of these tools, several sizes are required.

The "outline-tool," B, Fig. 1168, is chiefly used for separating one figure from another, and for outlines: *a* is the back of the tool; *b*, the face; *c*, the point; *d* is technically termed the belly. The horizontal line 1-2 shows the surface of the block. All the handles when received from the turner are circular, but as soon as the tool has been inserted, a segment is cut away from the lower part, so that the tool may clear the block. The blade should be very fine at the point, so that the line it cuts may not be visible when the block is printed, its chief duty being to form a termination to a number of lines running in another direction. Although the point should be fine, the blade must not be too thin, for it would then only make a small opening, which would probably close up when the block was put in the press. When the tool becomes too thin at the point, the lower part must be rubbed on a hone to enable it to cut out the wood instead of sinking into it. Nine "gravers" of different sizes, starting from the outline-tool, are sufficient for ordinary work. The blades as made are very similar to those used in copper-plate engraving; the necessary shape for wood engraving is obtained by rubbing the points on a Turkey stone. The faces, and part of the backs, of nine gravers are shown at C, Fig. 1168; the dotted line *a–c* shows the extent to which the tool is sometimes ground down to broaden the point. This grinding rounds the point of the tool, instead of leaving it straight, as shown at *a–b*. Except for the parallel lines, called "tints," these gravers are used for nearly all kinds of work. The width of the line cut out is regulated by the thickness of the graver near the point, and the pressure of the engraver's hand.

1168.



The parallel lines forming an even and uniform tint, as in the representation of a clear sky, are obtained by what is called the "tint-tool," which is thinner at the back, but deeper at the side, than the graver, and the angle of the face at the point is much more acute, as shown at D, Fig. 1168: *a* is a side view of the blade; *b* shows the faces of nine tint-tools of varying fineness. The handle is of the same form as that used for the graver. The graver should not be used in place of the tint-tool, as, from the greater width of its point, a very slight inclination of the hand will cause a perceptible irregularity in the distance of the lines, besides tending to undercut the line left, which must be carefully avoided. E, Fig. 1168, shows the points and faces of the two tools, from a comparison of which, this statement will be readily understood. As the width of the tint-tool at *b* is little more than at *a*, it causes only a very slight difference in the distances of the lines cut, if inclined to the right or the left, as compared with the use of the graver. Tint-tools that are strong in the back are to be preferred, as less likely to bend, and giving greater freedom of execution than weak ones. A tint-tool that is thicker at the back than at the lower part, leaves the black raised lines solid at their base, as at F, Fig. 1168, the block being less liable to damage than in the case of G, Fig. 1168, in which the lines are no thicker at their base than at the surface. The face of both gravers and tint-tools should be kept long rather than short; though if the point be ground too fine, it will be very liable to break. When, as at H, Fig. 1168, the face is long,—or, strictly speaking, when the angle formed by the plane of the face and the lower line of the blade is comparatively acute,—a line is cut with much greater clearness than when the face is comparatively obtuse, and the small shaving cut out turns gently over towards the hand. When, however, the face of the tool approaches to the shape seen at J, Fig. 1168, the reverse happens; the small shaving is ploughed out rather than cleanly cut out, and the force necessary to push the tool forward frequently causes small pieces to fly out at each side of the hollowed line, more especially if the wood is dry. The shaving, also, instead of turning aside over the face of the tool, turns over before the point, and hinders the engraver from seeing that part of the pencilled line which is directly under it. A short-faced tool of itself prevents the engraver from distinctly seeing the point. When the face of a tool has become obtuse, it ought to be ground to a proper form; for instance, from the shape of the figure K to that of L, Fig. 1168.

Gravers and tint-tools, when first received from the makers, are generally too hard—a defect that is soon discovered by the point breaking off short as soon as it enters the wood. To remedy this, the blade of the tool must be tempered to a straw-colour, and either dipped in sweet oil, or allowed to cool gradually. If removed from the iron while it is still straw-coloured, it will have been softened no more than sufficient; but should it have acquired a purple tint, it will have been softened too much, and instead of breaking at the point, as before, it will bend. A small grindstone is of great service in grinding down the faces of tools that have become obtuse. A Turkey stone is a very good substitute, as, besides reducing the face, the tool receives a point at the same time; but this requires more time. Some engravers use only a Turkey stone for sharpening their tools; a hone in addition is of great service. A graver that has received a final polish on a hone cuts a clearer line than one which has only been sharpened on a Turkey stone; it also cuts more pleasantly, gliding smoothly through the wood, if it be of good quality, without stirring a particle on either side of the line. The gravers and tint-tools used for engraving on a plane surface are straight at the point, as represented at M, Fig. 1168; but for engraving on a block rendered concave in certain parts by lowering, it is necessary that the point should incline slightly upwards, as at N, Fig. 1168. The dotted line shows the direction of the point used for plane-surface engraving. There is no difficulty in getting a tool to descend on one side of a part hollowed out or lowered; but unless the point is slightly inclined upwards, as shown, it is extremely difficult to make it ascend on the opposite side, without getting too much hold, and thus producing a wider white line than intended.

Gouges O, Fig. 1168, of different sizes are used for scooping out the wood towards the centre of the block; whilst flat tools, or chisels, are chiefly employed in cutting away the wood towards the edges, about $\frac{1}{8}$ in. below the subject. The gouge is similar to an ordinary carpenter's gouge, except that it is solid, being a round bar, with the end ground off at an angle. The other articles required are a sand-bag, on which to rest the block whilst engraving it; an agate burnisher and a dabber, which are used for taking proof-impressions of the woodcut; an oil-stone, and eye-glass with shade.

Holding the Graver.—Engravers on copper and steel, who have much harder substances than wood to cut, hold the graver with the forefinger extended on the blade beyond the thumb, as at P, so that by its pressure the point may be pressed into the plate. As boxwood, however, is much softer than these materials, and as it is seldom of perfectly equal hardness throughout, it is necessary to employ the thumb at once as a stay or rest for the blade, and as a check upon the force exerted by the palm of the hand, the motion being chiefly guided by the forefinger, as shown at Q, Fig. 1168. The thumb, with the end resting against the side of the block, in the manner represented, allows the blade to move backwards and forwards with a slight degree of pressure against it, and in case of a slip, it is ever ready to check the graver's progress. This mode of resting the thumb against the edge of the block is, however, only applicable when the cuts are so small as to allow the graver, when thus guided and controlled, to reach every part of the subject. When the cut is too large to admit of this, the thumb rests upon the surface of the block, as at R, Fig. 1168, still forming a stay to the blade of the graver, and checking at once any accidental slip.

Plugging.—If a slip or mistake occurs in a woodcut, it may be remedied by the insertion of a plug into a hole drilled in the block. If the error is a small one, the hole need not be deep; but if a large piece has to be inserted, it must be deeper in proportion. A plug is cut, of a round, taper shape; the small end is inserted in the hole, and the plug is driven down, without, however, using too much force. The top of the plug must then be cut off, and carefully brought to a smooth surface, level with the rest of the block; if this is not done, the plug will be visible on the print. If the error to be remedied happens to be in a long line, a hole must be drilled at each end, and the wood between the two holes removed by small chisels, the hollow space being filled up in a similar way to that described.

On Copper.—Engraving on copper is performed by cutting lines representing the subject on a plate of copper by means of a steel graver or "burin."

The Plate.—The plate must be perfectly polished, quite level, and free from imperfection; to this, must be transferred an exact copy of the outlines of the drawing. To do this, the plate is uniformly heated in an oven or otherwise, till it is sufficiently hot to melt white wax, a piece of which is then rubbed over it and allowed to spread, so as to form a thin coat over the whole surface, after which, it is left in a horizontal position till the wax and plate are cold. A tracing having been taken of the original design with a graphite pencil on a piece of thin tracing-paper, it is spread over the face of the prepared plate, with the lines downwards, and, being secured from slipping, a strong pressure is applied, by which operation the lines are nearly removed from the paper, being transferred to the white wax on the plate. The pencil-marks on the wax are now traced with a fine steel point, so as just to touch the copper; the wax is then melted off, and a perfect outline will be found on the copper, on which the engraver proceeds to execute his work.

The Tools.—Besides the graver, ending in an unequal-sided pyramidal point, the other instruments used in the process are a scraper, a burnisher, an oil-stone, and a cushion for supporting the plate. In cutting the lines on the copper, the graver is pushed forward in the direction required, being held at a slight inclination to the plane of the copper. The use of the burnisher is to soften down the lines that are cut too deeply, and for burnishing out scratches in the copper; it is about 3 in. long. The scraper, like the burnisher, is of steel, with three sharp edges to it; it is about 6 in. long, tapering towards the end. Its use is to scrape off the burr raised by the action of the graver. To show the appearance of the work during its progress, and to polish off the burr, engravers use a roll of woollen, or felt, called a rubber, which is used with a little olive-oil. The cushion, which is a leather bag about 9 in. in diameter, filled with sand, for laying the plate upon, is now rarely used except by writing engravers. For architectural subjects, or for skies, where a series of parallel lines is wanted, a ruling-machine is used, which is exceedingly accurate. This is made to act on an etching ground by a point or knife connected with the apparatus, and bit-in with aquafortis (commercial nitric acid) in the ordinary way.

Facing with Iron.—The relative hardness of iron and copper furnishes a means of greatly increasing the number of impressions that may be taken from a copper plate. Ordinary copper plates will not afford more than 800 good impressions without re-touching. This may be successfully increased to 2000 by electro-depositing a surface of iron upon the plate, and this surface may be renewed indefinitely. The necessary apparatus consists of a Bunsen's battery (20 elements) and a guttapercha-lined trough (45 in. long, 22 in. wide, 32 in. deep) filled with a solution of 100 lb. sal ammoniac to 1000 lb. water; to the positive pole of the battery, is attached a sheet of iron of the dimensions of the trough, and immersed in the liquid, while another plate of half the size is similarly fixed to the negative pole. After several days, the bath should be fit for use, the battery having meantime received necessary attention. The iron sheet at the negative pole is now replaced by the copper sheet to be coated, and momentary immersion should suffice to cover it with an iron deposit; if not, the bath is not yet ready. The copper plate must not remain in the bath after the bright iron coating appears blackish at the edges. Immediately the coated copper plate is removed from the bath, it is carefully washed under a water-jet of some force; when dry, it is again washed with spirit of turpentine, and is ready for printing from. Before re-coating the plate, the residue from the former coat must be removed by washing in nitric acid diluted with 8 parts of water, taking care to cleanse the plate from this acid liquid the moment the iron has disappeared, or the copper will begin to undergo similar destruction.

On Steel.—Engraving on steel is the same as copper-plate engraving, except in certain modifications in the use of the acids; therefore, so far as the process itself is concerned, no particular description is necessary; but the means employed for first decarbonizing and recarbonizing the steel plate, so as to reduce it to a proper state for being acted upon by the graving tool, must be explained. In order to decarbonate the surfaces of cast-steel plates, by which they are rendered much softer and fitter for receiving either transferred or engraved designs, fine iron-filings, divested of all foreign matters, are used. The stratum of decarbonated steel should not be too thick for transferring fine and delicate engravings; for instance, not more than three times the depth of the engraving; but for other purposes, the surface of the steel may be decarbonated to any required thickness. To decarbonate it to a proper thickness for a fine engraving, it is exposed for four hours to a white heat, enclosed in a cast-iron box with a tight lid. The sides of the box must be at least ⅜ in. thick, and at least a thickness of ½ in. of pure iron-filings should cover or surround the cast-steel surface to be decarbonated. The box is allowed to cool very slowly, by shutting off all access of air to the furnace, and covering it with a layer of 6–7 in. of fine cinders.

Each side of the steel plate must be equally decarbonated, to prevent it from springing or warping in hardening. The safest way to heat the plates is to place them in a vertical position. The best steel is preferred to any other for the purpose of making plates, and more especially when such plates are intended to be decarbonated. The steel is decarbonated solely to render it sufficiently soft for receiving any impression intended to be made thereon; it is, therefore, necessary that, after a piece of steel has been so decarbonated, it should, previously to being printed from, be again carbonated, or reconverted into steel capable of being hardened. In order to effect this recarbonization, or reconversion into steel, the following process is employed. A quantity of leather is converted into charcoal, by exposing it to a red heat in an iron retort until most of the vaporizable matter is driven off. The charcoal is reduced to a very fine powder; a box made of cast-iron of sufficient dimensions to receive the plate which is to be reconverted into steel, so that the intermediate space between the sides of the box and the plate may be about 1 in., is filled with the powdered charcoal. Having covered it with a well-fitting lid, it is placed in a furnace similar to those used for melting brass, where the heat is gradually increased until the box is somewhat above a red heat; it is allowed to remain in that state till all the vaporizable matter is driven off from the charcoal. The lid is removed from the box, and the plate is immersed in the powdered charcoal, taking care to place it so that it may be surrounded on all sides by a stratum of the powder of a nearly uniform thickness. The lid being replaced, the box, with the plate, remains in the degree of heat before described for 3–4 hours, according to the thickness of the plate so exposed; 3 hours are sufficient for a plate ½ in. thick, and 5 hours when the steel is 1½ in. After the plate has been exposed to the fire for the proper length of time, it is taken from the box, and immediately plunged into cold water. It is found by experience that the plates, when plunged into cold water, are least liable to be warped or bent when they are held in a vertical position, and made to enter the water in the direction of their length. If a piece of steel, heated to a proper degree for hardening, be plunged into water, and suffered to remain there until it becomes cold, it is very liable to crack or break, and, in many cases, it would be found too hard for the purposes for which it was intended. If the steel cracks, it is spoiled. Therefore, to fit it for use, should it not be broken in hardening, it is the common practice to heat the steel again, in order to reduce or lower its temper. The degree of heat to which it is now exposed determines the future degree of hardness, or temper, and this is indicated by a change of colour upon the surface of the steel. During this heating, a succession of shades is produced, from a very pale straw-colour to a very deep blue. It is found that, on plunging the steel into cold water, and allowing it to remain there no longer than is sufficient to lower the temperature of the steel to the same degree as that to which a piece of hard steel must be raised to temper it in the common way, it not only produces the same degree of hardness in the steel, but, what is of much more importance, almost entirely does away with the risk of its cracking. The proper temperature arrived at, after being plunged into cold water, can only be learned by actual observation, as the workman must be guided entirely by the kind of hissing noise which the heated steel produces in the water while cooling. From the moment of its first being plunged into the water, the varying sound will be observed; and it is at a certain tone, before the noise ceases, that the effect to be produced is known. As a guide, take a piece of steel which has already been hardened by remaining in the water till cold, and by the common method of again heating it, let it be brought to the pale-yellow or straw-colour, which indicates the desired temper of the steel plate to be hardened. By this experiment, as soon as the workman discovers the colour to be produced, he will be able to judge of the precise time at which the steel should be taken out. Immediately on withdrawing it from the water, the steel plate must be laid upon or held over a fire, and heated uniformly until its temperature is raised to that degree at which a smoke is perceived to arise from the surface of the steel plate after having been rubbed with tallow; the steel plate must then be again plunged into water, and kept there until the sound becomes somewhat weaker than before. It is taken out, heated a second time to the same degree as before, a third time plunged into water till the sound becomes again weaker than the last, exposed a third time to the fire as before, and for the last time returned into the water and cooled. After it is cooled, the surface of the steel plate is cleaned by heating it over the fire. The temper must be finally reduced by bringing on a brown, or such colour as may suit the purpose required. The engraving is effected by graving and etching like copper; for biting-in, a mixture of 1 part pyroligneous acid, 1 nitric acid, and 3 water is used; it is run off from the plate in less than a minute; the plate is rinsed in running water, and dried quickly. Stronger acid is used when a deeper tint is required.

Engraving Steel Cylinders.—A cylinder of very soft or decarbonized steel is made to roll, under great pressure, backward and forward on the hardened engraved plate, till the entire impression from the engraving is seen on the cylinder in alto-relievo. The cylinder is then hardened, and made to roll again backward and forward on a copper or soft steel plate, whereby a perfect fac-simile of the original is produced of equal sharpness.

On Stone.—Lithography, or engraving on stone, depends upon the following principles:—

(1) The facility with which calcareous stones imbibe water; (2) the great disposition they have to adhere to resinous and oily substances; (3) and the affinity between oily and resinous substances, and their power of repelling water. Hence, when drawings are made on a polished surface of calcareous stone, with a resinous or oily medium, their adhesion is so great that only mechanical means can effect their separation; and while the other parts of the stone take up the water poured upon them, the resinous or oily parts repel it. When, therefore, a coloured oily or resinous substance is passed over a stone prepared in this manner, it will adhere to the drawings, but not to those parts of the stone which have been watered.

The Stones.—The stones used in lithography come principally from Germany, but it is said that the Bavarian quarries are exhausted of the best kind, and that the finest stones are now obtained from Bruniquel, Tarn, and Garonne, in France, and a somewhat inferior quality from Vigan. A bed of lithographic stone 12 yd. thick has recently been discovered at Longinowka, in Galicia.

Stones are prepared for chalk drawings by rubbing two together, with a little silver sand and water between them, taking care to sift the sand from large grains, by which the surface would be scratched. The upper stone is moved in small circles over the under one, till the surface of each is sufficiently even, when they are washed, and common yellow sand is substituted for the silver sand, and produces a finer grain. They are then again washed clean, and wiped dry. It will be found that the upper stone is always of a finer grain than the under one. To prepare stones for writing or ink drawings, they are rubbed with brown sand, washed, and rubbed with powdered pumice; the stones are again washed, and each polished separately with a fine piece of pumice, or water Ayr-stone. Chalk can never be used on stones prepared in this manner. The same process is followed in order to clean a stone that has already been used.

The Ink and Chalk.—Besides the inks described on p. 1172, the following may be used:—Tallow, 2 oz.; virgin wax, 2 oz.; shellac, 2 oz.; common soap, 2 oz.; lamp-black, ½ oz. The wax and tallow are first put in an iron saucepan with a cover, and heated till they ignite; whilst they are burning, the soap is thrown in in small pieces, one at a time, taking care that the first is melted before a second is put in. When all the soap is melted, the ingredients are allowed to continue burning till they are reduced one-third in volume. The shellac is now added, and as soon as it is melted, the flame is extinguished. It is often necessary in the course of the operation to extinguish the flame, and take the saucepan from the fire, to prevent the contents from boiling over; but if any parts are not completely melted, they must be dissolved over the fire without being again ignited. The black is next added. When it is completely mixed, the whole mass is poured out on a marble slab, and a heavy weight is laid upon it to render its texture fine. The utmost care and experience are required in the making both the ink and chalk. Sometimes it is not sufficiently burned, and, when mixed with water, appears slimy: it must then be remelted, and burned a little more. Sometimes it is too much burned, by which the greasy particles are more or less destroyed; in this case, it must be remelted, and a little more soap and wax be added. This ink is for writing or pen-drawing on the stone. The ink for transfers should have a little more wax in it. The chalk consists of 1½ oz. common soap, 2 oz. tallow, 2½ oz. virgin wax, 1 oz. shellac, ½ oz. lamp-black, mixed in the same way as the ink.

The Transfer.—Transfer-paper for lithographic purposes is made in the following way:—½ oz. gum tragacanth is dissolved in water, strained, and added to 1 oz. glue and ½ oz. gamboge; 4 oz. French chalk, ½ oz. old plaster of Paris, and 1 oz. starch are powdered, sifted through a fine sieve, and ground up with the gum, glue, and gamboge; sufficient water is then added to give an oily consistence, and the compound is brushed on to thin sized paper. The drawing or writing, made on the prepared side of the transfer paper, is wetted on the back, and placed, face downwards, on the stone, which must previously be slightly warmed, say to about 52° (125° F.). The stone is passed through the press four or five times; the paper is then damped, and carefully removed.

Drawing on the Stone.—The subject is first traced on the stone in red, great care being taken not to touch the stone with the fingers. Or the drawing may be done by means of a black pencil; but this is objectionable, as it is difficult to distinguish the line from that made by the chalk or ink. Then, having a rest to steady the hand, the drawing is gone over with the chalk, pressing it with sufficient firmness to make it adhere to the stone. For flat tints, considerable practice is necessary to secure an even appearance, which is only to be obtained by making a great many faint strokes over the required ground. Lights may either be left, or, if very fine, can be scraped through the chalk with a scraper. If any part is made too dark, the chalk must be picked off with a needle down to the required strength.

Preparing for Printing.—After the drawing on the stone has been executed, and is perfectly dry, a very weak solution of nitric acid (1 part in 100 of water) is poured upon the stone, which not only takes up the alkali from the chalk or ink, as the case may be, leaving an insoluble substance behind it, but lowers, to a small extent, that part of the surface of the stone not drawn upon, thus preparing it to absorb water with greater freedom. Place the stone in a sloping position, then pour the solution over it, letting it run to and fro until it produces a slight effervescence. Then wash the stone with water, and afterwards pour weak gum-water over it. The acid, by destroying the alkali on the lithographic chalk, causes the stone to refuse the printing-ink except where touched by the chalk; the gum-water fills up the pores of the stone, and thus prevents the lines of the drawing from spreading. When the stone is drawn on with ink, there must be a little more acid used with the water than when the drawing is made with chalk. The roller charged with printing-ink is then passed over the stone, which must not be too wet, and the impression is taken by passing through a press, in the usual manner, the processes of watering and inking being repeated for every impression. If the work is inclined to get smutty, a little vinegar or stale beer should be put into the water that is used to damp the stone.

Engraving on Stone.—The stone must be highly polished. Pour the solution of aquafortis and water over it, washing it off at once. When dry, cover with gum-water and lamp-black; let this dry, then etch with a needle, as on copper. It is necessary to cut the surface of the stone through the gum, the distinction of light and dark lines being obtained by the use of fine- and broad-pointed needles. Rub all over with linseed-oil, and wash the gum off with water. The lines on the stone will appear thicker than they will print.

To Imitate Woodcuts on Stone.—Cover with ink those parts meant to be black; scratch out the lights with an etching-needle; the lines which come against a white background are best laid on with a very fine brush and lithographic ink.

To remove a Transfer.—The existing transfer is ground away by rubbing it with another piece of stone, putting sand between, using finer sand as it gradually wears away; then it is ground with rotten-stone, till of the requisite fineness for the next transfer.

Transferring from Copper to Stone.—In transferring from copper to stone, use is made of prepared paper, that is, ordinary unsized paper, coated with a paste of starch, gum arabic, and alum. About 60 parts of starch are mixed with water to a thinnish consistency over a fire; have 20 parts of gum ready dissolved, and also 10 parts of alum dissolved; when the starch is well mixed, put in the gum and alum. While still hot, coat the paper with it in very even layers; dry, and smooth out. Take an impression from the copper with the transfer-ink; lay the paper on the stone, damp the back thoroughly with a sponge and water, and pass through the lithographic press. If all is right, the impression will be found transferred to the stone, but it will, of course, require preparing in the usual manner. The great advantage gained is, that very many more impressions may be printed from stone than from a copper plate, and very much more quickly.

On Zinc.—Zincography differs only in a few details from lithography. All ordinary drawings may be made on zinc plates instead of stone, the materials and mode of printing being the same. The plates compete successfully with large stones on the scores of price and portability. The zinc employed is of the quality known as "best rolled vieille montagne." Irregularity of surface may be remedied by pressing. The coating of scale and oxide is removed by scraping, and the surface is then rubbed with pumice, &c., exactly like stone. All drawings on zinc are made on a grained surface, which is produced as in the case of stone, replacing the stone muller by one of zinc. When grained, the plate is washed first with cold and then with hot water, and dried rapidly. A once-used plate may be re-prepared by removing the ink by spirit of turpentine, washing first with water and then with strong alkali, pouring over a mixture of 1 part each sulphuric and hydrochloric acids in 24 parts water, washing again with water, and re-graining.

The drawing is made as on stone, and etching is then effected by one of the following mixtures:—(*a*) ¾ pint of decoction of nut-galls, made by steeping 4 oz. in 3 qt. water; for 24 hours, boiling up, and straining; ¼ pint gum solution, of creamy consistence; 3 dr. solution of phosphoric acid; (*b*) 1¼ oz. nut-galls boiled in 1¼ lb. water till reduced to ⅓, strained, and added to 2 dr. nitric acid and 4 drops acetic; (*c*) decoction of nut-galls simply. After etching, the sequence of operations is washing off; gumming in; drying by heat; washing off with turpentine, without moistening or removing the gum; rolling in till quite black; sprinkling with water, and continuing to roll and sprinkle till the plate is clean and the work is rolled up. Printing is performed as with stone, using an ink containing weaker varnish, and exercising somewhat greater precaution.

Photographic Processes.—Since the modern development of photography (see Photography, pp. 1532–44), a great number of printing processes, some remarkably simple, others more intricate, and many bearing a close general resemblance to each other, have been devised. These will now be noticed.

Willis's Aniline.—The process of W. Willis is founded on the action of bichromates on organic matter, the printed image being coloured by means of an aniline salt; it is extremely useful for copying plans and simple line-subjects. The operation is as follows:—Sized paper is floated in potassium bichromate containing a little phosphoric acid; it is next exposed beneath a translucent positive, and when the image of the latter is clearly shown, it is subjected to the action of aniline vapour. The result is that the parts shielded from the light by the lines of the positive are deeply coloured (green, black, or reddish, according to the aniline salt used), while the other parts retain the weak tint of the reduced chromium oxide. In developing the print, it is exposed to the contact of the vapour from aniline dissolved in spirit of wine, the solution being placed in a basin, and heated by a spirit-lamp. The prints are fairly permanent after washing.

Poitevin's Powder.—A mixture of gum arabic, sugar, and glycerine, with some sensitizing solution of potassium bichromate, is poured upon an impervious surface (e. g. a glass plate), and dried by warmth. Thus prepared, the plate is immediately exposed beneath a translucent positive for a few minutes. The parts affected by the light become hygroscopic, in proportion to the duration of the exposure, and intensity of the light, and any impalpable powder delicately brushed over the plate will adhere to the hygroscopic parts, according to their degree of moisture, thus forming a reversed copy. The developed image is coated with collodion, and transferred to paper unreversed, the soluble bichromate being washed out in the operation. Obernetter's recipe for the sensitizing solution is:—4 parts dextrine, 5 parts white sugar, 2 parts ammonium bichromate, 2–8 drops glycerine for every 100 *cc.* of water, and 96 parts water. The glass plate is sometimes previously coated with collodion.

Herschel's Cyanotype.—This process is in very common use by architects and engineers for copying plans, producing an image with white lines upon a blue ground. Sensitive paper is made by brushing it over with a solution of ferric oxalate (10 gr. to the oz.); it will remain good for years, if kept secure from light. The sensitive paper is exposed under the positive, and then brushed over with, or immersed in, a solution of potassium ferricyanide (red prussiate of potash), of almost any strength, by which the image is developed. The colour of the ground is deepened by subsequent washing with solution of potassium bisulphate. The ferric oxalate (peroxalate of iron) is prepared by saturating a hot aqueous solution of oxalic acid with ferric oxide (peroxide of iron). A better sensitizing solution may be prepared by mixing 437 gr. ammonium oxalate, 386 gr. oxalic acid, and 6 oz. water, heating to the boiling-point, and stirring in as much hydrated peroxide of iron as it will dissolve.

Pellet's—Pellet's process, which gives copies in blue lines on a white ground, is an improvement upon the white lines on blue ground, as a method of obtaining copies of drawings, inasmuch as it permits the subsequent tinting of the copies, and requires much shorter exposure. The original drawing is placed in a printing-frame, in front of a corresponding sheet of the sensitive paper (supplied by the inventor), composed of a piece of stout paper, coated with a mixture of perchloride of iron and some easily oxidizable organic substance. The frame being exposed for a minute in the sunshine, the per-salt of iron becomes reduced to a proto-salt wherever the sensitive paper is unprotected by the opaque lines of the original drawing. On removal from the frame, the exposed sheet is immersed in a strong solution of potassium ferrocyanide, and this substance, reacting with the per-salt of iron remaining on those parts of the paper protected by the opaque lines, produces Prussian blue, while the ground of the paper remains white. The print is washed, soaked in dilute hydrochloric acid, and washed again to remove traces of the acid.

Woodbury-type.—Woodbury's process is intended to produce a mould of a gelatine print, from which, other prints may be obtained. A thick film of sensitive gelatine, resting on a tough stratum of collodion, is placed beneath a negative with the collodion side next the image. After sufficient exposure to a light so arranged that the rays always fall in one direction, the gelatine picture is developed as if it were an autotype print, and presents the image in considerable relief. After drying, it is laid on a perfectly flat metallic plate, and a sheet of lead or some other soft metal is forced down upon it by a powerful press. The metallic sheet, being an exact mould of the gelatine picture, is put into a special press; and a viscous compound of gelatine dissolved in hot water, with the addition of fine pigment or permanent dye, is poured upon this sheet. Strongly-sized paper, of even texture, is placed upon the viscous compound, and the top plate of the press is brought down upon the mould, and firmly held, thus squeezing out the superfluous gelatine. The gelatine soon sets, when the top is raised, and the paper bearing the picture is detached. The print is immersed in alum solution, to render the impression insoluble. The top plate of the press is made of thick glass, and its surface is a perfect plane, to ensure the gelatine being squeezed out from the portions which are to be white in the picture, and to prevent a mottled and uneven appearance. Within certain limits concerning the size of white surface which can be produced (owing to the variations in the thickness of all paper), this process is capable of producing permanent images at a price but little greater than the cost of the paper and solution.

Photo-lithography.—Another process founded on the insolubility of gelatine when treated with a bichromate and exposed to light, is one capable of producing pictures in printing-ink, as well as in ink adapted to transferring to zinc or stone, images being reproduced by ordinary surface-printing from the transferred prints. The photographic negative is placed in a photographic printing- or pressure-frame, with a piece of prepared paper face downwards upon the picture side of the glass. The back is made secure, and the glass side is exposed to the light; in due time, it is taken to the dark-room, and coated with transfer-ink. Washing removes the transfer-ink from those parts which have not been affected by the light (the white parts of the paper), but leaves it where the light has acted (the lines of the picture); thus a photographic transfer is produced, and may be applied to stone or zinc, and printed from in the usual manner. The sensitizing solution is prepared as follows:—1–1½ oz. of gelatine (the smaller quantity if "flake") is set to soak in sufficient water to cover it; meantime, 1 oz. potassium bichromate is dissolved in 5 oz. water, and filtered; when the gelatine has plimmed, pour on sufficient boiling water to make 11 oz., and add the bichromate solution. Sometimes a dash of glycerine is added. This solution will keep good for a considerable time in a cool place. To prepare the paper, some of the solution is warmed to about 38° (100° F.), and sheets of the paper ("bank post," "positive photographic," or other fine-wove and slightly sized) are floated on it for 2–3 minutes, and hung up to dry in the dark-room, then again floated, and suspended from the opposite end. The sensitized paper is exposed in the ordinary manner beneath a negative in the pressure-frame, until the lines appear of a fawn-colour on a yellow ground.

The picture is transferred to stone or zinc by coating the latter with ink, laying the former face downwards upon it, and pulling through the press. Ordinary chalk lithographic ink may be used for single prints, but a superior ink is made as follows:—16 oz. lithographic ink and 8 oz. middle linseed varnish are first mulled together; 6 oz. Burgundy pitch and 2 oz. bitumen are melted over a clear fire till all the water is driven off; 1 oz. white wax is also melted; the whole is then mixed together, with 1 oz. palm-oil, and run into vessels for keeping. The print is developed by being floated back downwards on water at a temperature of 38°–50° (100°–122° F.), till the lines appear as depressions. It is then washed with water at about 70° (158° F.) on an inclined slab, by which, the soluble gelatine is removed with the ink that coated it, and the image remains as ink lines on ridges of insoluble gelatine. The developed print is washed in cold water, and hung up to dry; it is then ready for transferring to stone or zinc, being first damped till it becomes limp. The subsequent manipulation is a mere repetition of lithographic printing (see p. 1615).

Relief and Photo-engraving Processes.—Relief processes are those which produce plates or blocks with raised lines, capable of being printed from like type in an ordinary printing-press. They are adapted only to line drawings, and are unsuited for the reproduction of toned work. Engraved plates have the lines of the original drawing in depression, and are adapted to the same class of work as relief processes. Both are produced by the same general method and on the same principle, of which, the following is an outline. The foundation of the system is the fact that asphalt or bitumen, when exposed to light, becomes insoluble in its ordinary solvents if partially saturated. In Niépce's process, the first based on this ground, silver plates were coated with bitumen, the unaltered portions of which were dissolved away after exposure; iodine was applied, the remaining bitumen was removed, and the result was a metallic silver image on a ground of silver iodide. The solvent generally employed is chloroform. The coated plate is dried, and exposed beneath a subject. The portions to be protected from the influence of the light will depend upon whether the plate is to be engraved or in relief; in the former case, the lines will need protection. Care must be taken that the opacity, where required, is perfect. For engraved plates, a reversed positive is necessary; for relief blocks, an ordinary unreversed negative. The original picture is placed in contact with the prepared plate, and exposed as long as is considered necessary; the soluble portions of the bitumen are then removed by a nearly saturated solvent, leaving the metal bare. This latter may be zinc, copper, or steel; the first is most commonly used for relief blocks, while the two last are more convenient for engraving. The "biting-in," or development of the lines, is effected, in the case of zinc, by simple hydrochloric acid, though it is advisable to previously dip the plate in a sulphate of copper solution; for copper and steel, a mixture of hydrochloric acid and potassium chlorate is preferred. With relief blocks, the biting-in is a tedious operation, having to be carried as deep as in a wood-block. After the first biting, which gives the clear lines, the plate is heated, dusted over with rosin, and reheated to make the bitumen quit the lines, these operations being repeated till sufficient depth is attained. In appreciably large spaces, the metal is removed by engravers' tools.

Ehrard's biting-in process differs somewhat from the preceding. A transfer is prepared as for zincography, transferred to a copper plate, and plunged into an electro-plating bath for a few minutes, thus coating the copper with a thin silver film, while the lines are protected by the greasy ink; the plate is rinsed in dilute acid, and placed in a mercuric chloride bath, where a double chloride is formed; after washing, and removal of the ink, the biting-in proceeds.

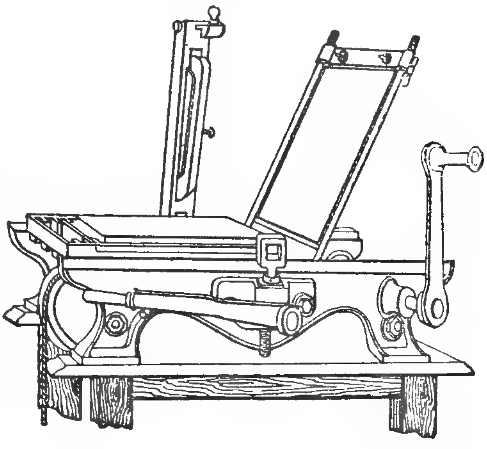
Fox Talbot proposed a modification, which consisted in printing the negative on a gelatine film, washing away the unaltered gelatine, and making an electrotype. Scamoni has some plan of building up a relief on the negative itself, and taking an electrotype from it. The foregoing methods, with perhaps some other modifications, are in extensive use on an industrial scale. Several firms are largely engaged in making relief blocks and photo-engravings, notably Leitch, Dallas, and Cattell, in London, besides many others on the Continent and in America. The illustrations in this Encyclopædia have been prepared by the first-named firm, from drawings on stone by B. Alexander, Castle Street, Holborn.

Much has been done in the more difficult task of reproducing half-tone drawings and photographs from nature, by Woodbury, Dallas, Lenoir, and others. A manager of Goupil's, named Roussillon, availing himself of the Woodbury-type process (see p. 1617), gives a grain to the picture by the action of light, suitably regulated, and thus obtains a mould capable of giving mezzo-tints from ordinary negatives. They require some mechanical touching-up, however. Lenoir has recently made public a new process for producing engraved plates from negatives photographed from nature, which is substantially as follows. A metallic plate is lightly coated with a mixture of albumen, carmine, and potassium bichromate. The carmine (for which, gamboge and various resins may be substituted with almost equal success) serves both as a dye and to assist in the lifting of the film, by its solubility in ammonia, drawing the albumen with it more or less in the stripping-off, the exposure having taken place upon the upper surface. When the film is stripped off, an image remains formed of albumen, in itself unable to resist the action of acids. It must, therefore, be rendered insoluble. There are two ways by which this may be effected; one is to cause the albumen to absorb a solution of gum lac, dissolved in hot water with borax; the other, and preferable, is to plunge the plate, once stripped, in a solution of potassium bichromate, then drying at about 49° (120° F.). The albumen by this means acquires the required resistance to the action of acids. The plate is next engraved, to give it a grain according to the amount of ink it should take up. Upon the unabsorbent and stripped plate, a film is spread, consisting of a solution of bitumen and turpentine mixed with carbonate of lime. When plunged in an acid bath, carbonic acid is liberated; it forms tiny canals, through which, the acid attacks the metal more or less quickly, by reason of the thickness of the albumen. The acid bath is composed of water acidulated with nitric and oxalic acids and alum. An oxalate of the metal is thus formed on the sides of the canals, and causes them to adhere to the plate. The texture of the etching is more or less fine according to the length of time the albumen is allowed to absorb the acid. In this state, the plate is finished; it requires only to be dried, and is ready to be printed from immediately. No preliminary preparation is necessary, as the whole operation may be conducted in three hours.

Warnerke has recently published some improvements based upon the discovery that a gelatine plate submitted to pyrogallic acid becomes insoluble in the parts exposed to light. The ordinary gelatine process requires very accurately-timed exposure; but with the pyrogallic acid, and using the emulsion on paper, no amount of over-exposure will do harm, provided the developer is sufficiently restrained. The transfer of the image from the paper to glass is very simple. The former is immersed in water, and placed in contact with a glass plate; the superfluous moisture is removed by a squeegee, and the paper is stripped off, leaving the gelatine on the glass, when the application of hot water dissolves all the gelatine not acted upon by the light, and the image is left in relief on the glass. Intensification is effected by mixing with the emulsion a non-actinic colouring matter which is not affected by silver; aniline colours answer the purpose well. Relief is said to be obtained far more easily than by the ordinary bichromatized gelatine, and the process is therefore specially applicable to Woodbury-type. It may also be adapted to engraving, enamelling, and collotype purposes.

Collotype Processes. — Several methods of collotype printing have been described under Photography (p. 1543). Impressions may be obtained in a lithographic press, but the form shown in Fig. 1169 is especially adapted to this process.

1169.



Edwards' Heliotype.—The most important of the many modifications of the collotype process is the "heliotype" invented by Ernest Edwards, wherein the great advantage consists in toughening the gelatine film by means of chrome-alum. His method is briefly as follows:—The solution of gelatine and bichromate, with the due proportion of chrome-alum, is poured upon the previously waxed surface of a carefully levelled glass plate, and dried, when the film is readily detached. The latter resembles a piece of thick paper, and may be similarly handled. After exposure in contact with a negative, the film is placed on a plate of zinc or pewter under water, and firmly attached by passing an indiarubber "squeegee" sharply over the surface of the film. The printing film on its plate is soaked in water sufficiently long to remove the superfluous bichromate, to prevent the further action of the light, and is then ready for the press. This is preferably on the vertical principle, such as the Albion printing-press. The inking possesses peculiar features a very stiff ink may be used to give the deepest shadows, and this may be followed by a thinner ink, even one more or less coloured, for the half-tones, thus producing a bichromatic effect in a single printing. The time occupied in drying the film is 24–36 hours at 32° (90° F.); 1500 copies have been successfully taken from one plate; one man can print 200–300 copies daily; for very long numbers, it can hardly compete with lithography in price, but for moderate numbers, the cost is very small.

Capt. Waterhouse has introduced a modified process, as follows:—The sensitive film is laid on flat copper plates, finely grained on one side. After levelling on the drying-apparatus, the plates are washed with warm water, and coated on the grained side, while still wet, with a mixture of 15 *grm.* Nelson's opaque gelatine, and 4 *grm.* powdered potassium bichromate, in 100 *cc.* water, adding 4 *cc.* formic acid when the first are dissolved. This is applied like collodion, and the excess is poured off. The coated plates are replaced in the drying-apparatus, and covered over. In about 2 hours at 50° (122° F.), the films dry with a fine, even, glossy surface, perfectly free from streaks and waviness. It is best to let the plates harden for a day or two before use.

Bibliography.—H. Fitz-Cook, 'Graphotype: a process for producing from drawings blocks for surface printing' (Jour. Soc. Arts, Vol. xiv., No. 681, London: 1865); J. Pratt, 'Machine for Type-writing' (Jour. Soc. Arts, Vol. xv., No. 754, London: 1867); E. Edwards, 'Photography in the Printing-press: a description of the Heliotype process' (Jour. Soc. Arts, Vol. xix., No. 962, London: 1871); J. L. Ringwalt, 'American Encyclopædia of Printing' (Philadelphia: 1871); J. R. Johnson, 'Improvements in the Manufacture of Printing Types' (Jour. Soc. Arts, Vol. xxi., No. 1061, London: 1873); 'Type-writing Machines' (Jour. Soc. Arts, Vol. xxiv., No. 1213, London: 1876); J. Husnik, 'Das Gesammtgebiet des Lichtdrucks' (Vienna: 1877); T. Mac Kellar, 'The American Printer' (Philadelphia: 1878); J. Krüger, 'Die Zinkogravure' (Vienna: 1878); J. Husnik, 'Die Heliographie' (Vienna: 1879); F. J. F. Wilson, 'Stereotyping and Electrotyping' (London: 1880); E. Bigmore and C. Wyman, 'Bibliography of Printing' (London: 1880); F. J. F. Wilson, 'Printing-machines and Machine-printing' (London: 1880); W. D. Richmond, 'Grammar of Lithography' (London: 1880); T. Bolas, 'Modern Autographic Printing Processes' (Jour. Soc. Arts, Vol. xxviii., No. 1417, London: 1880); F. Noble, 'Principles and Practice of Colour Printing' (London: 1881); G. Field, 'Grammar of Colouring' (London); P. B. Watt, 'Hints on Colour and Printing in Colours' (London); 'Printers' Register' (London: 1872–); 'Printing Times and Lithographer' (n. s. London: 1875–).

(See Ink; Photography.)

RESINOUS AND GUMMY SUBSTANCES (Fr., *Matières Résineuses et Gommeuses*; Ger., *Harz- und Gummi-arten*).

Resinous and gummy substances may be primarily divided into three great classes—gums, resins, and indiarubbers; each of these classes may be split into a number of sub-sections.

1. Gums.—The term "gum" is properly restricted to those exudations from the stems, branches, and fruits of plants, which dissolve or soften in water to a slimy liquid state, or at least to a gelatinous consistency; which refuse to dissolve in alcohol of 60 per cent.; which yield mucic and oxalic acids when treated with nitric acid; and which are capable of conversion (by sulphuric acid) first into dextrine and then into sugar. The form, surface, colour, transparency, density, microscopic characteristics, and optical properties scarcely admit of any generalization, and will best be noticed under the individual substances. As to the chemical constitution of gums, all natural vegetable gums (thus excluding dextrine) are substantially composed of one or more of the three bodies—bassorine, arabine, and cerasine. Bassorine is a pure hydrocarbon; arabine and cerasine are hydrocarbons combined with mineral bases. Bassorine is devoid of colour, odour, and flavour; it is insoluble in water and alcohol, but heated in the former, assumes a gelatinous character; dried at 100° (212° F.), its formula is $C_6H_{10}O_5$. Arabine is a compound of arabic acid with lime and some potash or magnesia; it is a colourless, odourless body, of acid reaction, forming with water a glutinous, frothy solution; on burning, it leaves an ash consisting chiefly of carbonate of lime, but containing also some carbonate of potash. Arabic acid is a white substance, soluble in water, and reddening litmus; its solution dries to a colourless, amorphous body; dried at 100° (212° F.), its formula is $C_{12}H_{22}O_{11}$. Cerasine is a colourless body, insoluble in water and alcohol, but, like bassorine, swelling in the former to a kind of gelatine; it is a compound of metagummic acid and lime. Natural gums also contain water (12–17 per cent.), dextrine, sugar, tannin, colouring matter, and mineral ingredients; they afford 2–3 per cent. of ash.

Concerning the origin of gums. They were formerly supposed to be secretions of plants; recent researches, however, have clearly proved that at least some gums are formed from the whole tissue of the cell-walls, by chemical metamorphosis. This is considered certain in the case of tragacanth, cherry, and arabic gums. [The reader is referred to some special remarks on tragacanth under that head, pp. 1685–6.] Wiesner holds the same view with regard to moringa and

Indian tragacanth (kuteera) gums. Accordingly it happens that gums are yielded most abundantly when the plants are in a sickly state, caused by a fulness of sap in the young tissues, whereby the new cells are softened and finally decomposed; the cavities thus formed fill with liquid, which exudes, dries, and constitutes "gum," which, in structure, is quite amorphous, being neither crystallized nor organized. Gum is one of the most common plant-products. It occurs abundantly in the living rind of many plants, and exudes upon the surface of the bark. In the woody structure, it occurs more seldom, and in smaller quantity. The sources of the most important gums may be seen from the following synopsis:—

Mimoseæ.—Acacia spp., giving Arabic (including Senegal, Suakin or Talca, Morocco or Barbary, Cape, E. India, and Australia or Wattle), and Kuteera (Indian Tragacanth); *Prosopis spp.* (Mezquite); *Parkia spp.*

Papilionaceæ.—Astragalus spp. (Tragacanth).

Drupaceæ.—Prunus spp., and *Amygdalus spp.* (collectively Cherry gum).

Anacardiaceæ.—Anacardium occidentale (Cadjii); *Spondia spp.; Odina spp.* (Ging and Kunnee); *Rhus Metopium.*

Aurantiaceæ.—Feronia elephantum (Wood-apple).

Meliaceæ.—Melia Azedarach.

Ternströmiaceæ.—Cochlospermum gossypium (Kuteera [Indian Tragacanth]).

Bombaceæ.—Adansonia digitata.

Sterculiaceæ.—Bombax spp.; Sterculia spp. (contributing to Kuteera).

Cactaceæ.—Cactus spp.; Opuntia spp.

Moringaceæ.—Moringa pterygosperma (Moringa).

Bromeliaceæ.—Puya spp. (Chagual).

Palmaceæ.—Cocos nucifera (Coco-nut).

Gums may be divided into the following four classes:—

(1) Arabinic.—These consist essentially of arabine; cerasine and bassorine are either quite absent, or in very minute proportion. The chief are—Arabic (all kinds), Wood-apple, and Cadjii gums.

(2) Cerasinic.—Contain varying proportions of cerasine and arabine. The Cherry group.

(3) Bassorinic.—Essentially composed of bassorine. Embraces Tragacanth, Kuteera, Coco-nut, Chagual, and Moringa gums.

(4) Cerasino-bassorinic.—Compounded of cerasine and bassorine. Kuteera (some kinds).

2. Resins.—Under the term "resins," are included all the hard, friable, natural plant-substances, externally resembling gums; insoluble in water; soluble in ether and alcohol; rich in carbon; poor in oxygen; free from nitrogen; and burning with a smoky flame. No resin is a definite chemical compound, but rather a complicated mixture. The essential ingredients of resins are the resin-acids—substances rich in carbon; some of them displace the carbonic acid in alkaline carbonates, and form with the alkalies the so-called resin-soaps, which froth in water. Besides the resin-acids, natural resins contain volatile oils, gums, and often cinnamic and benzoic acids, as well as the ordinary components of plant-tissues—cellulose, tannin, humic bodies.

The older chemists classified resins into "hard," "soft," and "feather." The two first are now combined as "resins" simply, their difference in hardness being only a matter of degree, while most of the soft resins become hard in time. "Feather" resins denoted indiarubbers, which are now excluded from the resins altogether, on the ground of both physical and chemical dissimilarities, and will receive a separate description. The usual classification now adopted by Continental chemists is threefold:—(1) True resins, (2) gum-resins, (3) balsams. The gum-resins differ from true resins only in containing some gum. Balsams include both resins which are rich in volatile oil, the latter assuming a resinous character, or holding a great portion of the resin in solution, thus forming a syrupy mass (such as turpentine and Canada balsam); and bodies which in outward character resemble the resinous balsams (like Peru), and are chemically poor in resinous matters, though rich in a fluid neutral substance bearing some likeness to certain resins. The classification adopted by M. C. Cooke differs considerably from the foregoing. Omitting the gums, which have been already dealt with, he forms three groups—gum-resins, resins, and oleo-resins. The gum-resins embrace three classes—emulsive, fetid, and fragrant, the last being again sub-divided into sections, represented respectively by bdellium and benzoin. The true resins he distinguishes as hard or copalline (sub-classified as pale and dark), and soft or elemi. While his oleo-resins embrace balsams, natural varnishes, and turpentines and tars (the two last grouped together). Usually in England, however, the term gum-resin is applied to an inspissated milky plant-juice, consisting of a gum soluble in water, associated with a resin and a volatile oil soluble in alcohol, and containing other vegetable and a little mineral matter. The general acceptation of the term "balsam" is an oleo-resin, or natural compound of a resin and an essential oil, in such proportions as to form a viscous or semifluid mass. From the solid resin to the limpid essential oil are insensible gradations, and few resins are hard at the moment of their exudation. The proposal to confine the term balsam to such bodies as contain cinnamic (or an analogous) acid, in addition to the resin and essential oil composing the oleo-resin, has not been carried out; but the fragrant balsams containing cinnamic or benzoic acids are regarded as a distinct class by authorities on materia medica, though Cooke includes under the term all the oleo-resins, except the natural varnishes (acrid lacquers) and the turpentines and tars.

Of the physical characteristics of the resins generally, the first to be considered are their form and size. The hard resins have a drop-like, stalactitic, or knotty form. When the resin spreads over the surface of the plant and there collects, it is usually drop-like or stalactitic; when it flows into the ground, it becomes knotty. Other forms are rare. The drops, as met with in commerce, are generally pretty constant in shape for each kind, but the stalactitic and knotty form vary much in that respect. Some commercial resins are shaped by artificial means—dragon's-blood in sticks or tears, gamboge in cylinders, shellac in laminæ.

The surface of many resins forms an important characteristic. In red xanthorrhœa, the surface which was in contact with the stem is rough, dull, unresinified, and possesses structural peculiarities that will be detailed when speaking of it in particular. Many resin-surfaces present polygonal excrescences, with regular crystallographic form. In Zanzibar copal, these are visible by the naked eye; and in sandarach, by the aid of a glass.

Resins seldom present a definite structure, as they occur for the most part in thick homogenous masses. But benzoin, yellow xanthorrhœa, and the softer kinds of dragon's-blood exhibit a structure known as amygdaloidal to mineralogists. It is produced by a number of rounded grains imbedded in the mass, and differing from it in colour. Some sorts of turpentine-resin are permeated by globular pores of various size.

Most resins are quite amorphous; few contain crystalline substances, and still fewer occur as crystals themselves. The turpentines often hold abietic acid in the form of crystals. In the turpentine-resins, a crystalline body is frequently visible. In the elemi-resins, which are very rich in crystalline components, it often happens that the optical properties of the mass so nearly approach those of the crystals, that the latter only become visible after dissolving the amorphous portion in alcohol.

The optical properties of the resins seldom afford any guide.

The colours of the resins are in many cases pronounced, as the yellowish-brown of gamboge, the red of dragon's-blood and red xanthorrhœa, the white of Siam benzoin, and the black of some rosins. Many resins are colourless; the tints of most lie between yellow and brown.

In transparency, the resins vary much. Some are as transparent as glass (certain copals); others are quite opaque (xanthorrhœa, dragon's-blood). Most are merely translucent to the naked eye. Microscopic sections, even of the quite opaque, are at least translucent, and often communicate their own colour to the transmitted light.

The lustre of most resins is almost adamantine, and constitutes a degree termed "resinous" by mineralogists. There also occur those of fatty (small sorts of benzoin, and dragon's-blood) and of waxy (the "almonds" of benzoin) lustres, and some are lustreless (certain elemi-resins).

The fracture is mostly glassy, often conchoidal; sometimes also smooth, granular, earthy, and splintery.

The hardness of most resins lies between gypsum and rock salt; only the best copals are harder than the latter, and for the verification of these, hardness is one of the best tests.

The density (sp. gr.) is for many resins a distinctive feature, e. g. many copals. In general, the sp. gr. of resins is somewhat greater than that of water, while the gum-resins are considerably heavier, e. g. asafœtida 1·3. The balsams are mostly lighter than water. The specific gravities of some of the resins are shown in the annexed table:—

Table of Specific Gravities of Resins at 15°–16° (60° F.).

Pine-rosin, yellow transparent	1·083–1·084	Copal, very old	1·054–1·055
" whitish opaque	1·044–1·047	Benzoin, Siam	1·235
" dark colophony	1·100	" Penang	1·145–1·155
Shellac, light coloured	1·113–1·114	" Borneo	1·165–1·170
" darker	1·123	Guaiacum, pure	1·236–1·237
" bleached	0·965–0·968	Amber	1·074–1·094
Dammar, old	1·075	Sandarach	1·038–1·044
Copal, E. Indian	1·063–1·070	Mastic	1·056–1·060
" W. Indian	1·070–1·800	Tolu, old brittle	1·231–1·232

In tenacity, most resins are friable; some are soft (stick-lac, shellac), some pliant (elemi). The degree of friability can be tested by scratching the surface with a needle: the most friable show a splintery scar; the least, a smooth line.

Many resins, both coloured and colourless, give a white streak, even the dark-hued colophony.

Some resins, finely disseminated through water, exhibit a rapid molecular movement; others a very indolent one. The most pronounced occurs in the case of gamboge; copal powder, on the other hand, moves very slowly.

Several resins possess highly characteristic odour and flavour.

The secretion or imprisonment of organic débris in resins is much more frequent than is commonly supposed. The fragments are mostly invisible, except through the microscope, and chiefly consist of particles of bark and wood from the stems of the plants, which have become imbedded during the concretion of the resin. The recognition of these remains in a resin is often of importance, the more or less decomposed tissue illustrating the characteristics of the resin, as well as indicating its origin and derivation.

Many resins, and at least all produced by the metamorphosis of the cell-tissues, contain also tissue-remains (e. g. dragon's-blood, xanthorrhœa). These are the more valuable according as the metamorphosis has been more complete. Red xanthorrhœa often shows pieces of tissue between the resinified masses. Organic remains not derived from the resin-forming organs of the plant also occur; e. g. fungi. Thus the fine green crust which coats old specimens of gamboge is due to a delicate mycelium fungus.

The microscopic examination of resins at once reveals some facts concerning their origin. While the structure of red xanthorrhœa, exhibiting all stages from unresinified to completely resinified tissue (according to Wiesner), indicates that this resin is solely due to chemical metamorphosis of the whole tissue, the microscope shows that gamboge must exist in solution in the tissue of the plant-stem, and consequently proceeds from a cellular secretion. Gamboge really consists of a gummy groundwork permeated by microscopic grains of resin. On cutting the gamboge tree, the resin-holding sap escapes, and mingles with the watery sap of other tissues, and thus occurs the secretion of the hard resin.

Dragon's-blood originates much in the same manner as xanthorrhœa; and according to the researches of Karston and Wigand, it is probable that the ordinary resins of the *Coniferæ* (rosins) are produced in the same way. But it must not be supposed that the metamorphosis from the cellulose of the cell-walls to the resin is simple and direct. It is indirectly evident that the cell-walls of the resinified tissue, before their complete conversion into resin, yield a quantity of tannin. This tannin seems to be a medium between the hydrocarbon and the resin. In the resinification of whole tissue, it is doubtless not only the cell-membrane, but also more or less of the cell-contents, that is utilized. When a resin, like mastic, occurs in ready-formed veins, and is not produced by the resorption of cells or whole tissue, it must be considered as a secretion-product.

The melting-point is a characteristic test for different kinds of resin, and even for different grades of the same kind. The lowest met with is that of Siam benzoin—75° (167° F.); the highest, that of the hardest copals—360° (698° F.) The solubilities of the various resins in such solvents as alcohol, ether, carbon bisulphide, turpentine-oil, cajuput-oil, chloroform, &c., are well-known guides to their identification (see pp. 1624–7).

The resins exhibit no such chemical relationship as do the fats, for instance. Some few show a general resemblance, e. g. mastic, sandarach, dammar, olibanum; but the greater number are not only dissimilar, but do not even admit of being grouped under sections. Resins are as a rule very complicated bodies, and their origin, as previously explained, makes it difficult to expect otherwise. The classification of resins according to the effects of simple reagents is impossible, and recourse has been had to oxidation with caustic alkali, with or without dry distillation. Hlasiwetz has proved in some resins a family relationship with the aromatic series, which clearly indicates that many resins are derived from essential oils; indeed from the terpenes (e. g. turpentine-oil, lavender-oil), colophony-like resins can be produced by oxidation, and it is quite probable that the so-called terpene-resins exist in the plants as essential oils. The terpene-resins are weak, sometimes crystalline, acids. Nature affords them mixed with unaltered terpene, which may be distilled off with water. The terpene-free resin is odourless, hard, and but little changed by caustic alkali. Many aldehydes are converted into resins by oxidation; acryl-resin and the resin of acetic aldehyde are familiar examples.

That resins are among the most widely-distributed plant-products, is well known. They are found in almost all forms of vegetable life, even in fungi. They chiefly occur in the bark, and either flow out over its surface, or aggregate within it. The chief resin-yielding plants are as follows:—

Leguminosæ.—Myrospermum spp. (Peru, Tolu); *Vouapa spp.; Copaifera spp.* (Copaiba).

Cæsalpiniæ.—Trachylobium spp., Hymenæa spp. (Copal, Jutahy-seca).

Anacardiaceæ.—Pistachia spp. (Mastic, Chian turpentine); *Rhus spp.*

Amyridaceæ.—Boswellia spp. (Frankincense, Olibanum); *Icica spp.* (Copal, Elemi); *Bursera spp.* (Elemi); *Canarium spp.* (Dammar); *Amyris spp.; Hedwigia balsamifera; Balsamodendron spp.* (Bdellium, Elemi, Myrrh, Balm of Gilead); *Elaphrium spp.*

Humiriaceæ.—Humirium spp.

Zygophyllaceæ.—Guaiacum officinale (Guaiacum).

Rhamnaceæ.—Zizyphus Jujuba (Lac).

Euphorbiaceæ.—Pedilanthus spp.; Euphorbium spp. (Euphorbium).

Dipterocarpæ.—Vateria indica (Piney); *Shorea spp.* (Dammar); *Hopea spp.* (Dammar); *Dryobalanops spp.* (Camphor); *Dipterocarpus spp.* (Gurjun); *Vatica sp.*

Combretaceæ.—Terminalia spp.

Bixineæ.—Lætia resinosa.

Guttiferæ.—Garcinia spp. (Gamboge); *Calophyllum spp.* (Tamanu and Tacamahaca); *Moronobea coccinea* (Hog).

Hyperiaceæ.—Vismia spp. (Gamboge).

Cistaceæ.—Cistus spp.

Hederaceæ.—Hedera helix.

Umbelliferæ.—Ferula spp. (Galbanum, Sagapenum); *Scorodosma fœtida, Narthex asafœtida* (Asafœtida); *Opoponax Chironium* (Opoponax); *Dorema ammoniacum* (Ammoniacum); *Thapsia garganica; Bolax spp.*

Rubiaceæ.—Gardenia spp. (Dika-mali).

Apocynaceæ.—Tabernæmontana utilis.

Asclepiadaceæ.—Cynanchum viminale.

Convolvulaceæ.—Convolvulus scammonia (Scammony); *Ipomœa purgans* (Jalap).

Compositæ.—Carlina gummifera; Ceradia furcata (Bdellium).

Styracaceæ.—Styrax spp. (Benzoin, Storax).

Artocarpaceæ.—Artocarpus integrifolia.

Moraceæ.—Ficus spp.

Altingiaceæ.—Liquidambar spp. (Storax).

Aquilariaceæ.—Aquilaria spp. (Lignum Aloes or Agar).

Betulaceæ.—Betula alba.

Coniferæ.—Abies spp., Pinus spp. (Rosin, Turpentines); *Araucaria spp.; Dammara spp.* (Copal, Dammar); *Callitris spp.* (Sandarach); *Juniperus communis.*

Liliaceæ.—Dracæna spp. (Dragon's-blood); *Xanthorrhœa spp.* (Xanthorrhœa).

Palmaceæ.—Dæmonorops spp. (Dragon's-blood).

Detection of Resins, Gum-resins, and Balsams.—The following scheme for the recognition of the more important resins, gum-resins, and balsams (oleo-resins) is due to Hirschsohn, whose researches in this direction are well known. The reagents employed are:—(1) Sulphuric acid, sp. gr. 1·820; (2) alcoholic hydrochloric acid, obtained by saturating 95-per-cent. alcohol with dry hydrochloric acid gas; (3) solution of 1 part bromine in 20 parts chloroform; (4) saturated solution of calcium chloride in distilled water at the ordinary temperature; (5) solution of 1 part perchloride of iron in 10 parts 95-per-cent. alcohol; (6) saturated solution of neutral lead acetate in 95-per-cent. alcohol; (7) solution of ammonia, sp. gr. 0·980; (8) solution of pure sodium carbonate crystals in distilled water; (9) Frohde's test: 1 *centigram* sodium molybdate in 1 *cc.* sulphuric acid; (10) impure chloral hydrate, containing alcoholate; (11) saturated solution of iodine in petroleum-spirit boiling at 60° (140° F.). The author's names have been retained: they sometimes differ from those adopted in this article, and it is not always apparent what precise product is intended in the absence of the botanical source, e. g. Borneo copal.

Completely soluble in Chloroform.

Completely soluble in Ether.

A. Ethereal solution becomes turbid after addition of alcohol.
  - I. Alcoholic solution gives with perchloride of iron a turbidity that disappears on boiling. Chloral reagent colours violet—*Canada Balsam.*
  - II. Alcoholic solution gives no turbidity with perchloride of iron.
    1. The drug is liquid and forms a clear mixture with petroleum-spirit boiling below 40° (104° F.).
      - *a.* Bromine solution colours the chloroform solution yellowish, then violet and blue—*Maranham Copaiba.*
      - *b.* Bromine solution produces no colour—*Para Copaiba.*
    2. The drug is solid, and dissolves only partially in petroleum-spirit. Iodine solution colours red-violet—*Ordinary Mastic.*

B. Ethereous solution forms clear mixture with alcohol.
  - I. Perfectly soluble in alcohol.
    1. Perchloride of iron colours the alcoholic solution blue.
      - *a.* Lead acetate gives a precipitate with alcoholic solution. Sulphuric acid dissolves the drug with a cherry-red colour—*Guaiacum.*
      - *b.* Lead acetate gives no precipitate. Sulphuric acid dissolves the drug with a yellow-brown colour—*Carana Resin* (*Aceyta americana*).

2. Perchloride of iron colours the alcoholic solution brownish or greenish.
  - *a.* Lead acetate gives with the alcoholic solution a precipitate that is not dissolved by boiling.
    - α. Sodium carbonate solution dissolves part at the ordinary temperature. Chloral test colours the evaporation-residue of a petroleum-spirit extract gradually red-violet with blue streaks—*Coniferous Rosins.*
    - β. Sodium carbonate dissolves none or a very small quantity.
      - i. Petroleum-spirit extract colourless. Chloral test produces no colour or a very faint greenish—*Bombay Mastic.*
      - Petroleum extract coloured.
      - ii. Dark-brown. Chloral test colours brown—*Mani Resin.*
      - iii. Yellow-brown. Chloral test colours gradually indistinct red-violet—*Carana Resin.*
      - iv. Yellow-brown. Chloral test and bromine solution colour a magnificent violet—*Carana hedionda.*
  - *b.* Lead acetate gives with the alcoholic solution a precipitate that dissolves on boiling.
    - α. Bromine solution colours red—*Peruvian Guaiacum.*
    - β. Bromine solution produces no coloration—*Alexandrian Mastic.*
  - *c.* Lead acetate gives no precipitate. Ammonia gives a turbid mixture—*Dragon's-blood.*

II. Imperfectly soluble in alcohol.
  1. Lead acetate produces turbidity which disappears upon warming—*Brazilian Copaiba.*
  2. Lead acetate gives no precipitate. The drug is clearly crystalline. Sodium carbonate does not dissolve it by boiling.
    - *a.* Bromine solution gradually colours green.
      - i. Alcoholic hydrochloric acid colours violet, blue, or brown—*Elemi.*
    - *b.* Bromine solution colours violet—*Elemi.*
    - *c.* Bromine solution produces no colour—*Elemi (Amyris elemifera).*

Imperfectly soluble in Ether.

A. Perfectly soluble in alcohol.
  - I. Sulphuric acid colours the evaporation-residue of a petroleum-spirit extract cherry-red. The drug is free from cinnamic acid—*Siam Benzoin.*
  - II. Sulphuric acid does not colour such residue, or only faintly light-brown. Contains cinnamic acid—*Sumatra Benzoin* or *Tolu Balsam.*
  - III. Sulphuric acid colours such residue yellow-brown passing into violet—*Black Peru Balsam.*

B. Imperfectly soluble in alcohol.
  - I. Perchloride of iron gives a precipitate, which is neither dissolved by boiling nor soluble in ether—*Brazilian Copal.*
  - II. Perchloride of iron produces no turbidity or only a slight one that disappears on boiling.
    1. The ethereous solution gives with alcohol a turbid mixture.
       - α. Alcoholic hydrochloric acid colours it brownish. Chloral test colours evaporation-residue of petroleum-spirit extract greenish—*Dammar.*
       - *b.* Alcoholic hydrochloric acid colours it brick-red. Chloral test colours the petroleum-spirit residue carmine-red to violet—*White Peru Balsam.*
    2. Ethereous solution gives with alcohol a clear mixture.
       - *a.* Ammonia gives with alcoholic solution a clear mixture. Bromine solution colours blue—*Ceradia Resin.*
       - *b.* Ammonia gives with the alcoholic solution a turbid mixture. Bromine solution colours greenish—*Mecca Balsam.*

Imperfectly Soluble or Insoluble in Chloroform.

Completely soluble in Ether.

A. Ethereous solution red. Ammonia gives with alcoholic solution a clear mixture—*Dragon's-blood from Pterocarpus Draco.*

B. Ethereous solution yellowish or colourless.
  - I. Alcoholic solution gives with lead acetate no precipitate—*Podocarpus Resin.*
  - II. Alcoholic solution gives with lead acetate a precipitate that is not dissolved by boiling—*Sandarach.*

Imperfectly soluble in Ether.

A. Ethereous solution becomes turbid after addition of alcohol.
  - I. Alcoholic solution gives with ammonia a clear mixture.
    1. The mixture with ammonia is yellow. The solution of the resin in sulphuric acid is yellow-brown and gives with alcohol a clear violet mixture—*Eryops Resin.*
    2. The mixture with ammonia is carmine-red—*Sonora Lac.*
  - II. Alcoholic solution gives with ammonia a turbid mixture.

1. Perchloride of iron colours green. The drug contains cinnamic acid. Lead acetate gives a precipitate—*Liquid Storax.*

2. Perchloride of iron colours brownish or not at all.

a. The drug contains cinnamic acid, and gives with lead acetate no precipitate—*Liquidambar Balsam.*

b. The drug contains no cinnamic acid, and gives with lead acetate a precipitate—*Euphorbia Tirucalli Resin.*

B. Ethereous solution gives with alcohol a clear mixture.

I. Perfectly soluble in alcohol. Perchloride of iron colours dark-brown or black.

1. Solution in alcohol is red.

a. Lead acetate gives no precipitate. Chloroform extract colourless—*Xanthorrhœa quadrangularis Resin.*

b. Lead acetate produces turbidity. Chloroform extract yellow—*Xanthorrhœa arborea Resin.*

2. Alcoholic solution yellow. Lead acetate produces a precipitate—*Yellow Xanthorrhœa Resin.*

II. Imperfectly soluble in alcohol.

1. Alcoholic solution gives with ammonia a clear mixture.

a. Ammoniacal mixture is violet. Lead acetate gives a violet precipitate—*Lac.*

b. Ammoniacal mixture is yellow or colourless.

α. Perchloride of iron colours the alcoholic extract black. Lead acetate gives no precipitate—*Gamboge.*

β. Perchloride of iron gives a precipitate which is neither soluble in ether nor by heating. Lead acetate gives a precipitate.

i. Readily and completely soluble in ether-alcohol.

ii. Bromine solution precipitates the resin from the chloroform solution—*Australian Copal.*

iii. Bromine solution produces no precipitate—*Manilla Copal.*

iv. Imperfectly soluble in ether-alcohol—*E. Indian* and *African Copal.*

2. The alcoholic solution gives with ammonia a turbid mixture.

a. Perchloride of iron gives a precipitate that is neither dissolved by boiling nor in ether—*Borneo Copal.*

b. Perchloride of iron gives no precipitate.

α. Completely soluble in ether-alcohol. Chloral test colours evaporation-residue of petroleum-spirit extract blue to blue-violet—*Liquidambar styraciflua Balsam.*

β. Incompletely soluble in ether-alcohol.

† The drug contains sulphur.

i. Yields umbelliferone by dry distillation.

ii. Hydrochloric acid colours the evaporation-residue of the petroleum-spirit extract reddish-yellow; the chloral test colours it green—*Persian Sagapenum.*

iii. Hydrochloric acid colours the residue blue-violet; chloral test colours it rose-colour to raspberry-red and violet—*Levant Sagapenum.*

iv. Not coloured by hydrochloric acid. The solution of the drug in sulphuric acid is yellow-brown with a blue fluorescence. Potassium nitrate colours the gum-resin malachite-green—*Ordinary Asafœtida.*

v. Yields no umbelliferone by dry distillation.

vi. Sodium carbonate solution colours the drug light-brown, and the extract is not altered by acetic acid or lead acetate—*Asafœtida from Ferula alliacea.*

vii. Sodium carbonate solution forms an emulsion that cannot be filtered.

viii. Lead acetate gives no precipitate. Iodine solution is not altered—*Indian Bdellium.*

ix. Lead acetate produces immediately or after a short time a precipitate that dissolves upon warming. Iodine solution is not altered—*African Bdellium.*

†† The drug contains no sulphur.

i. Yields umbelliferone by dry distillation.

ii. The evaporation-residue of the petroleum-spirit extract is coloured by hydrochloric acid and the chloral test.

iii. Hydrochloric acid colours reddish-yellow; the chloral test colours green—*Persian Galbanum.*

iv. Hydrochloric acid colours red-violet; the chloral test colours greenish—*Levant Galbanum as at present in commerce.*

v. Hydrochloric acid colours violet-blue; the chloral test carmine-red—*Older Specimens of Levant Galbanum.*

vi. Hydrochloric acid gives no colour; the chloral test colours light-brown—*African Ammoniacum.*

vii. Yields no umbelliferone by dry distillation.

viii. Chloride of lime solution colours the gum-resin orange-yellow—*Persian Ammoniacum.*
ix. Chloride of lime solution produces no colour. Lead acetate gives no precipitate.
x. Iodine solution is not altered; the chloral test colours greenish—*Olibanum.*
xi. Iodine solution is not altered; the chloral test gives no colour—*Indian Myrrh.*
xii. Chloride of lime solution produces no colour. Lead acetate gives a precipitate.
xiii. Bromine solution colours violet-red; the chloral test colours violet—*Ordinary Myrrh.*
xiv. Bromine solution produces no colour or only yellowish. Perchloride of iron colours green—*Opoponax.*
xv. Bromine solution produces no colour or only yellowish. Perchloride of iron colours brownish—*Euphorbium.*

INDIARUBBERS.—This group includes all plant-substances which, in physical characteristics, resemble or approach indiarubber. The physical properties of indiarubber are so remarkable and peculiar that it is difficult to mistake whether a plant belongs to this group or not. It comprises the various kinds of indiarubber, guttapercha, balata, &c. These products have hitherto been obtained exclusively from the milky saps of certain plants. This milk is not confined to the plants affording supplies of indiarubber, but occurs also in members of other families, as the *Papaveraceæ* (*Papaver somniferum*, or opium-poppy) and the milky *Compositæ* (*Lactuca, Cichorium, Sonchus*).

The milky sap of indiarubber-yielding plants lies chiefly in the middle layer of the bark, and is contained in a network of minute tubes ("laticiferous vessels"), which, in the *Apocynaceæ*, are found also in the inner bark or bast layer. Examinations of this sap are less complete than they might be, and have mostly been made upon samples transported from S. America in closed vessels. A specimen analysed by Faraday gave 31·70 per cent. caoutchouc, 7·13 wax and bitter principle, 2·90 matter soluble in water but insoluble in alcohol (? gum), 1·90 albumen, 56·37 water, acetic acid, and salts. The acidity was clearly due to fermentation. The fresh milks of some European uphorbias (*Euphorbia Cyparissias* and *E. platyphylla*) reveal the presence of water, resin, caoutchouc, essential oil, albumen, gum, yellowish-brown extractive matter, sugar, starch, fatty oil, tartaric acid, malic acid, &c. The chief ingredients are:—

	E. Cyparissias.	E. platyphylla.
Water	72·13	77·22
Resin	15·72	8·12
Gum	3·64	2·15
Caoutchouc	2·73	0·73

Their respective sp. grs. at ordinary temperatures are 1·0449 and 1·0468.

According to Adriani, the fresh milk of indiarubber and guttapercha plants appears under the microscope as a kind of emulsion, a clear liquid having suspended in it minute ($\frac{1}{12250}$ in. diam.) globules of caoutchouc. Raw balata exhibits the same appearance. The milk of the above-named euphorbias coagulates on exposure to the air. The same is the case with indiarubber. That the caoutchouc is held in suspension in the juice by the agency of ammonia, gains probability from the fact that many of the fresh milks have an ammoniacal odour, and that the addition of liquid ammonia is resorted to as a preventive of coagulation. Exposure of the milk to the air causes a change (usually reddening) of colour. The presence of an indiarubber in a plant may always be detected by making an incision, and testing whether the exuding milk will coagulate into an elastic fibre when rubbed between the fingers. An incision in the dry bark of such plants will disclose parallel elastic threads. The main distinctive features of all the members of this group are their elasticity, and their insolubility in water, alcohol, alkalies, and organic acids. Their composition is somewhat complex, and their market value depends upon a proportionate abundance of the elastic substance, with a relative absence of a certain oxidized, viscid, resinous body soluble in alcohol, and whose formation is in great measure prevented by rapid evaporation of the milk, and other means of avoiding oxidation.

In quantity, indiarubber and its allies are found in numerous tropical and subtropical plants of the families *Euphorbiaceæ, Apocynaceæ, Asclepiadaceæ, Sapotaceæ, Lobeliaceæ, Artocarpaceæ*, and *Moraceæ*. The following list embraces the chief plants yielding indiarubber-like products:—

Euphorbiaceæ.—Hevea [*Siphonia*] *spp.* (Pará Indiarubber); *Manihot Glaziovii* (Ceará Indiarubber); *Mabea spp.*; *Omphalea cordata*; *Sapium spp.*; *Euphorbia spp.*

Apocynaceæ.—Urceola elastica, Willughbeia spp. (Borneo Indiarubber); *Vahea spp.* (Mozambique or Madagascar Indiarubber); *Hancornia speciosa* (Mangabeira or Pernambuco Indiarubber); *Landolphia spp., Tabernæmontana sp.* (African Indiarubber).

Asclepiadaceæ.—Calotropis gigantea, Cryptostegia spp., Alstonia spp. (Indiarubber).

Sapotaceæ.—Isonandra [*Dichopsis*] *spp.* (Guttapercha); *Sideroxylon attenuatum*; *Mimusops spp.* (Balata).

Lobeliaceæ.—Siphocampylus sp.

Artocarpaceæ.—Castilloa spp. (Central American Indiarubbers); *Artocarpus integrifolia; Cecropia peltata.*

Moraceæ.—Ficus spp. (Assam and Java Indiarubber); *Urostigma spp.* (African Indiarubber).

It will have been observed that the preceding classifications necessarily exclude an artificial product such as dextrine or British gum, and the fossilized resins of which amber is the chief, as well as one or two bodies, which, though really astringent extracts, are commonly included among gums,—the kinos and mochurrus. This fact, combined with the want of uniformity in different systems of classification, and the disregard for all classification exhibited by the mercantile classes, renders it inadvisable to continue a grouped arrangement in dealing with each product in particular. The following sections will therefore be arranged in alphabetic order according to the commercial names of the most important—Amber, Ammoniacum, Arabic, Asafœtida, Balata, Balm of Gilead, Bdellium, Benzoin, Cadjii, Chagual, Cherry, Chicle, Chironji, Coco-nut, Copaiba, Copal and Animi, Dammar, Dextrine, Dhoura, Dika-mali, Dragon's-blood, Elemi, Euphorbium, Frankincense, Galbanum, Gamboge, Ging and Kunnee, Guaiacum, Gurjun, Guttapercha, Guttashea, Indiarubber, Jumrasi, Jutahy-seca, Kauri, Kino, Kos, Lac, Mahogany, Mango, Mastic, Mezquite, Mochurrus, Moringa, Myrrh, Nagdana, Olibanum, Opoponax, Orange, Peru balsam, Phormium, Piney, Pitches, Retinite, Rimu, Rosin, Sagapenum, Sandarach, Sarcocolla, Satinwood, Schraufite, Storax, Tamanu and Tacamahaca, Tars, Tendoo, Thus, Tolu balsam, Tragacanth, Turpentines, Varnishes, Wood-apple, Xanthorrhœa. To these, will be appended an alphabetic list (under botanical names) of the less important plants known to afford resinous, gummy, or balsamic exudations.

Amber (Fr., *Ambre, Succin, Carabé*; Ger., *Bernstein, Agtstein*).—Amber is a fossilized resin yielded by trees that are supposed to have grown upon the greensand beds of the Cretaceous formation, the forest originally reaching probably from Holland over the German coast, through Siberia and Kamschatka, even to N. America. The tree affording this resin, an extinct species of pine, has been provisionally named *Pinites succinifer*, but Göppert has proved that the product is not necessarily from a single species, nor even confined to the *Coniferæ* at all.

The amber supply obtained from the Baltic region of Prussia is more important than the combined contributions of all other districts. In W. Prussia, the resin is found not only in the sea and on the shore, but also in a minor degree in the hilly interior. In the latter case, however, "nests" are rare, and the yield and profit of the scattered diggings are trifling. E. Prussia, and especially the part called Samland, is the great amber-producing centre. Here, particularly at Wansen, Lassan, Groskuhren, Klienkuhren, Kraxtepellen, Kreislacken, Hubnicken, and Palmnicken, amber-mining is a settled industry. The productive stratum is a "blue earth," a loose, bluish sandstone, the lower member of the marine Tertiary formation of the locality. It has a thickness of 8–28 ft., the lowest 7–11½ ft. alone being worked. The depth is 108 ft. below the surface, and 46 ft. below sea-level. The ground is worked by shafts and levels, in the ordinary way, but with extraordinary precautions against inrushes of sea-sand and water. The ground as picked down is sent to surface, and there undergoes examination. This consists in washing it with water through a long inclined trough, whose entrance is barred by a grating of 2½–3-in. apertures, to arrest large masses, which require careful breaking by hand. Men armed with nets are stationed at 6-ft. intervals along the trough, and pick out all valuable pieces. The "tailings" or waste from the trough escapes through a 0·315-in. sieve into the sea. Recently, jigging-machines have been introduced in lieu of the troughs and net-men. Their sieves have a gauge of 0·118 in., through which the earthy matters are washed, leaving the amber on the surface. These machines (20) pass 350 cwt. of earth an hour. The average output of the mines is 15,000–25,000 tubs (of about ½ ton) a month, yielding 60–120 cwt. of large, and 22–36 cwt. of small amber, the former embracing all sizes from 100 gr. to 2½ lb. The cost of production is estimated at 4*s*.–6*s*. 6*d*. a lb. The mean yield of amber is 1 *kilo.* (2·2 lb.) for every 20 cub. ft. excavated. The average local value is placed at 1*s*. 3*d*. a lb. for small, and 7*s*. 6*d*. for large. In the three years 1876–8, the total production from about 13 acres of this ground (some 160 acres have been proved or worked) was 208¼ tons of large and 60½ tons of small amber, with a total value of 174,350*l*. The working is a monopoly of the Prussian government, who received in royalties for that period 44,664*l*.

The area of the amber-bearing stratum of E. Prussia is far from being satisfactorily determined. Moreover, there is reason to believe that other strata exist at deeper levels than the one now being worked, as considerable quantities of the resin are found among soil washed away by the sea, during heavy gales, from those portions of the coast sand-hills that lie at a lower horizon. This is known as *fliesen* amber, in contradistinction to the *erd* amber of the mines; it is softer and of less uniform colour. This marine amber is obtained by dredging at Schwarzort, on the Kurische Haff, near Memel, and by diving at Brüsterort. The yield of the former is of considerable importance, amounting to 80,000–90,000 lb. annually. The resin is found almost uniformly in separate nodules, with lignite, disseminated in the sand, at a depth of 10–12 ft. The dredged-up sand is sent ashore, and washed in the same way as the earth from the mines. The production of amber in E. Prussia in 1870 was 1415 cwt., of which, the dredging at Schwarzort contributed 740 cwt.; the diving at Brüsterort, 300 cwt.; the mines in Samland, 55 cwt.; the fishing along the coast, 320 cwt. This was much below the average, in consequence of the war. In 1874, some 360,000 lb., of all sizes and qualities, were exported.

The occurrence of amber outside the German empire is very trivial and precarious, and the products are said to be of different origin. Stray pieces occasionally found on the coasts of Norfolk, Suffolk, Essex, and Sussex, and on the Swedish and Danish shores, usually after severe storms, are doubtless washed from the Baltic beds. It sometimes occurs in the sandy deposits of the London clay at Kensington, and associated with bituminous deposits in the Paris clay; also in the French departments of Aisne, Loire, Gard, and Bas-Rhin, as well as near Basle, in Switzerland. The shores of the Adriatic and the coasts of Sicily likewise afford specimens; those from the latter often have a green or violet-blue colour. Some years since, an extensive bed of yellow amber was discovered in sinking a well near Prague, and pieces weighing 2–3 lb. were produced. Roumania possesses amber-deposits in the mountains of Sibicio, Valley of Bugeo, which, rationally exploited, might become important. The prevailing colour of the product is brown, but all shades occur, from orange-yellow or red to black, blue, and green, sometimes with specks and veins of several tints. The supply is always diminishing in quantity and in the size of the pieces. In N. Burma, amber-beds are found at an elevation of 1050 ft., to the S.-W. of the Mien Khorm plain, in the Hukong Valley. Pits are sunk to a maximum depth of 40 ft., the lower half penetrating a greyish-black carbonaceous earth. American localities where amber is met with are Cape Sable, near Magothy River, Maryland; Gay Head, near Trenton, and Camden, New Jersey; and, more recently, near Vincentown, New Jersey. All the specimens are found in the greensand formation. The sp. gr. of the Vincentown amber is less than that of water.

The principal markets for amber are Constantinople, Vienna, Moscow, Paris, London, and New York; the German towns chiefly engaged in the trade in raw and worked amber are Dantzig, Königsberg, Stolpen, Breslau, and Lübeck. The commercial varieties of the resin are divided into seven classes, based upon physical characteristics:—(1) "Shining" (*luisant*), pale-yellow or greenish; (2) "bastard" (*bâtard*), opaque, citron-yellow to dark-yellow; (3) "bone-coloured" (*couleur d'os*), dull-white, very rich in succinic acid; (4) "agate-coloured" (*couleur d'agate*); (5) "impure," containing organic remains; (6) "cloudy" (*nuageux*), unequally coloured, mainly clear-yellow; (7) "transparent," of various colours. The values vary widely with the size, form, and colour of the pieces, and the kind most esteemed in one market is neglected in another. An approximate scale of prices is as follows:—For mouth-pieces: 1 lb. in 9 pieces, 66*s.*; 1 lb. in 18 pieces, 45*s.*; 1 lb. in 40 pieces, 30*s.*; 1 lb. in 60 pieces, 19*s.* 6*d.*; 1 lb. in 100 pieces, 12*s.*; 1 lb. in 200 pieces, 9*s.*; for beads: 1 lb. in 30 pieces, 30*s.*; 1 lb. in 60 pieces, 18*s.*; 1 lb. in 100 pieces, 12*s.*

Crude amber occurs in commerce in pieces of irregular size and form; that from the mines is usually angular, with a rugose surface, while that from the sea is generally somewhat rounded by attrition, and smooth. The fracture as a rule is conchodial, and more or less lustrous. The consistence is solid, hard, and brittle. The sp. gr. commonly ranges between 1·05 and 1·095, the average being 1·065–1·070. Amber is devoid of odour and flavour at ordinary temperatures, but it affords a strong pleasant aroma when rubbed, pulverized, or burned. It is on this account employed in the perfume called *eau de luce* (see Perfumes, p. 1532). The gradations of colour have already been alluded to. Blue is due to ferric phosphate; cloudiness is caused by enclosed water in ordinary cases, but by excess of succinic acid (often in the free state) in the bone-like specimens. The cloudiness produced by entangled water can be completely removed by boiling in oil. Exposure to light darkens the colour of light-tinted amber. Amber is almost completely insoluble in water, ammonia, acetic acid, carbon bisulphide, benzol, and petroleum-spirit; slightly soluble in alcohol, ether, turpentine, chloroform, and volatile oils; and completely soluble in alkaline solutions containing camphor, and in a mixture of alcohol and turpentine-oil heated in a closed vessel. On boiling for 20 hours in linseed- or rape-oils, or heating for 40 hours in a sand-bath, it becomes transparent and ductile, allowing itself to be moulded into any form, and even enabling pieces to be cemented together. Subjected to dry distillation, it affords amber-oil (see p. 1416), succinic acid, and a solid residue. The applications of amber are chiefly as an article of ornamental turnery for the mouth-pieces of pipes and cigar-holders and for beads; for the preparation of a superior varnish (see Varnish); and for the production of amber-oil and succinic acid. As a medicinal agent it is extinct; and as a perfume, is chiefly used in the East. Our imports of it are on an increasing scale:—in 1853, 43 cwt.; in 1867, 60 cwt.; in 1870, 329 cwt. It is very extensively replaced by a false amber composed of copal, camphor, and turpentine, and costing but a mere fraction of the price of the true article. Simple tests by which the two substances can be distinguished are:—(1) Heated on a plate, the false will soon melt, while the true will bear a high temperature; (2) covered with sulphuric ether, the false is dimmed and softened, so that a penknife will pierce it; (3) on ignition, the true swells but does not run, while the false melts at once into drops; (4) amber is insoluble in cajuput-oil, while copal is quite soluble; (5) amber emits sulphuretted hydrogen when strongly heated.

Ammoniacum (FR., *Gomme-Ammoniaque*; GER., *Ammoniakgummi*).—The true ammoniacum of commerce is produced chiefly, if not exclusively, by *Dorema Ammoniacum.* This plant, the *ushak* of the Persians, occurs over a wide stretch of the barren country of W. Asia, particularly in the Persian provinces of Farsistan, Irak, and Khorasan. Bunge and Bienert place its north-western limit at Shahrud, S.-E. of Asterabad, whence it ranges eastwards to the deserts lying to the S. of the Sea of Aral and the Sir-Daria, while southwards it has not been met with beyond Basiran, a village of S. Khorasan (in 32° N. lat., and 59° E. long.). Dr. Grant found it abundantly in Syghan, near Bamian, on the N.-W. slope of the Hindu-Kush Mountains. One of the chief localities for the production of the gum-resin is the desert plain about Yezdikhast, between Ispahan and Shiraz.

The plant attains a height of 7 ft., and almost all portions of it, the stem, roots, leaves, and fruits are permeated by a milky juice, which escapes abundantly on the slightest puncture. Artificial tapping is not resorted to, the operation being performed by beetles, which, in the month of May, attack the plants in multitudes, and pierce them all over. The juice exudes in drops, which rapidly harden in the sun, and either remain attached to the plant, or fall to the ground. The product of this exudation, together with minor quantities which ooze out from the 3–4-year-old roots, and from the fibrous crown of the root, is collected in July–August by the peasants, and sold to dealers for transport to Ispahan or the coast. The gum-resin reaches Europe by way of the Persian Gulf and Bombay. The imports into Bombay from the Gulf were 327 cwt. in 1869–70, 520 cwt. in 1870–1, 164 cwt. in 1871–2, and 1671 cwt. in 1872–3; the re-exports from Bombay to the United Kingdom were 453 cwt. in 1871–2.

The ammoniacum of commerce is distinguished as "tear" and "lump"; the former constitutes the hardened drops in their separate form, while the latter is composed of concreted masses of these drops, more or less contaminated with gross foreign matters. The tears are dry grains of roundish form, varying in size from a millet-seed to a nut. Externally, their colour is pale cream-yellow; internally, opaque milk-white. Long keeping darkens their outer appearance to cinnamon-brown. At ordinary temperatures, the tears are hard and brittle, with a dull waxy lustre on the fractured surface, which is conchoidal. They readily soften by heat, particularly if recent. The "lumps" have a marbled or granitic appearance, and are sometimes softer, greasier, and more adhesive than the tears, sometimes harder, more brittle, and more lustrous, but always far less pure. The gum-resin has always a characteristic, non-alliaceous odour, and a bitter, acrid flavour. Its prominent constituents are resin (70 per cent.), essential oil (3–4 per cent.), gum, and water. It is used medicinally (see Drugs—Ammoniacum, Sumbul, pp. 793, 826), and in some cements.

Other Persian species of *Dorema* are capable of yielding gum-resins, though they are not known to contribute to the commercial supply. The exudation from the plant called *zah* by the Kurds, *D. Aucheri*, affords a very good article. These species, however, are far less abundant than the one producing the officinal drug. No attempt seems to have been made to cultivate any of these plants in India or Australia, though the conditions for success would appear to be present.

Moroccan or African Ammoniacum must not be confounded with the Persian product just described. It is an object of commerce with Egypt and Arabia, where it is employed, as of old, in fumigating. The plant affording it is called *fashook* in Arabic, and has been hitherto referred to *Ferula orientalis*, or *F. tingitana*; but Hooker and Ball consider it decidedly an *Elæoselinum*, probably *E. humile.* Leared was told that this plant grows at a place two days from Mogador, on the Morocco road; but Hooker and Ball were assured that it is found nowhere along that route, nor nearer to it than El Araiche, a place lying north of Morocco city, which is confirmed by information gathered by R. Drummond Hay, to the effect that it occurs near Morocco, and chiefly around Tedla. Lindley and others would extend the habitat of the plant to all N. Africa, as far as Syria, Rhodes, and Chios, and into Armenia and the E. Caucasus. But the product is obtained only in a very circumscribed district of Morocco, as stated, and is shipped occasionally at Mazagan and Mogador. It occurs in large, compact masses, of dark colour, formed by the agglutination of greenish or fawn-coloured tears. The main constituents are 67 per cent. resin and 9 per cent. gum. It is readily distinguished from the Persian officinal article by resisting the effects of hypochlorites, while the latter assumes a bright-orange hue by their action.

The approximate London market value of ammoniacum is 30–40*s.* a cwt. for drop, and 12–36*s.* for siftings and blocky.

Arabic (FR., *Gomme Arabique*; GER., *Acaciengummi*, *Arabisches Gummi*).—The term "gum Arabic" is sanctioned by long commercial use, and is therefore retained here, but it is quite misplaced, only a trifling proportion of a single variety of the product being derived from Arabia. The plants yielding the many forms of this useful gum are all species of *Acacia*, a genus of shrubs or trees widely diffused in the warmer regions of the globe. The principal acacia-gums may be best described under the separate titles by which they are known in commerce, viz.:—Picked Turkey, or White Sennar; Senegal; Suakin, Savakin, Talca, or Talha; Morocco, Mogador, or Brown Barbary; Cape; E. Indian (Babul, Siris, and Kheir); and Australian or Wattle.

1. *Picked Turkey or White Sennar.*—This is the produce of *Acacia Senegal* [*A. Verek, Mimosa Senegal*], a species not exceeding 20 ft. in height, which grows abundantly, constituting extensive forests, in the sandy region of W. Africa, mostly north of the Senegal river. Its negro name in this district is *verek.* In S. Nubia, Kordofan, and the Atbara country of E. Africa, where the tree is also found, it is called *hasbab.* Schweinfurth's testimony, corroborated by other authorities, is to the effect that this tree alone affords the fine white gum of the Upper Nile and Kordofan. The gum usually exudes spontaneously from the trees, without requiring any mutilation of the bark; but the natives of the Somali country, opposite Aden, are accustomed to supplement the natural outflow by scoring long wounds on the stems and branches. In Kordofan, the masses of gum aggregated upon the bark are removed by an axe, and gathered in baskets. The most highly valued kind, the *hashabi,* from Dejara province (Kordofan), is despatched from El Obeid and Bara to Dabbeh, and thence down the Nile into Egypt, or from Mandjara down the White Nile. The Samhara coast, towards Berbera, produces a good gum, part of which is shipped at Massowa; some, however, reaches Egypt by way of Jedda, in the Arabian Hejaz, whence it is called Hejazi or Jedda gum. The gum collected in the Somali country is of three grades, styled Felick, Zeila, and Berbera. The first is gathered chiefly by the Magartam Somalis, and those who inhabit the district around Cape Gardafui. This is esteemed the best. None of it finds its way to Aden, but a little reaches Maculla and Shehr on the Arabian coast, and the mass is bought up by Banians, and shipped direct to India. In Somali Land, when the gum of a district is gathered, it is sewn up in goat-skins, and carried on camels to the great Berbera fair, or to some of the small coast settlements, for shipment to Aden or Bombay. The plant is common in Yemen and Hadramaut, but the Arabs collect very little gum from it. The natives on the S.-E. coast, between Aden and Maculla, also collect a little, but scarcely any of this is exported.

2. *Senegal.*—This variety is produced by the same species of *Acacia* as the foregoing, and is in many respects identical with it. There are three distinct harvests per annum of this gum in the French colony of Senegal. The first, whose produce is termed *gomme du bas du fleuve,* takes place in November, during the windy season following the floods. The concreted exudations of gum are removed from the branches by means of crooked sticks. It is generally buried in the still damp soil, to remove the excessive moisture; it loses much of its weight and worth by drying, and usually accumulates a coating of sand. The second crop, *gomme du haute du fleuve,* or *gomme de Galam,* is completely dry when taken from the trees, and, being carried direct to store, is much cleaner than the first. The third contribution, *gomme friable,* or *Salabreda,* comes from Upper Senegal; it is extremely friable, owing, it is said, to the annual conflagrations in the forests, and is low-priced. During the harmattan winds, the gum exudes from the bark of the trees in tears, and solidifies in the open air, the amount of exudation depending upon the force and duration of the wind. The principal districts in which Senegal gum is produced on the one side are the country of the Brakna and Tararza Moors, the Galam country, Bondou, and Bambouk; and on the other, Oualo, Cayor, and Djolof. The three chief forests producing gum for the trade with Europe are:—That of Alfatak (Afatac), situated about 15 leagues from the river, opposite Podor, and extending to Lake Cayor, occupying a large portion of the Brakna country; (2) that of Liebar (El Ebiar), 30–40 leagues from the river, in the country of the Darmancour Moors, and containing many small trees affording red gum (? *A. nilotica*); (3) that of Sahel, in the territory of the Tararza Moors, the produce of which is carried to Gahé. This last forest consists exclusively of trees yielding white gum, and it is this product which is carried to Portendick for sale to English traders. Senegal gum is exported almost entirely to Bordeaux. Here it undergoes minute classification, the chief kinds being:—(1) *Blanche,* a fine, white gum, used in pharmacy, confectionery, distilling, and for dressing calico, linen, and lace; (2) *petite blanche,* similar, but smaller; (3) *blonde,* fine gum of pale-brown tint; (4) *petite blonde,* similar, but smaller, used for gumming envelopes and dressing ordinary cotton fabrics; (5) 2me *blonde,* darker than and inferior to the last, but used for like purposes; (6 to 9) *gros grabeaux. moyens grabeaux, menus grabeaux,* and *grabeaux triés,* different qualities of the more friable gum, less clear and more cracked in the interior than the first five grades; (10, 11) *friable blanche* and *friable blonde,* better qualities of the friable kind; (12, 13) *fabrique* and *petite fabrique,* especially selected for dressing textiles; (14) *poussière,* siftings, used for ink, blacking, and paint; (15) *marrons et bois,* contains fragments of wood, averaging 27 per cent. of the whole, and is used for similar purposes; (16) *boules naturelles,* in orange-sized lumps, largely used in the silk-manufactories of Lyons. Several other minor distinctions are recognized. Senegal gum on the whole is usually yellowish or reddish, and has less of the fissures so common in Picked Turkey, therefore much firmer and less readily broken. The presence of vermicular pieces is characteristic.

3. *Suakin, Savakin, Talca, or Talha.*—This kind is afforded by the *talch, talha,* or *kakul* (*A. stenocarpa*) and by the *ssoffar* (*A. Seyal*). The best quality, *hashabi el Jesire,* comes from Sennar,

on the Blue Nile; an inferior grade is sent from the barren plateau of Takka, lying between the E. tributaries of the Blue Nile and the Atbara and Mareb, as well as from the highlands of the Bisharrin Arabs, between Khartum and the Red Sea. The transport of the gum is effected by way of Khartum or El Melkheir (Berber), or, much more extensively, by Suakin (Savakin), on the W. coast of the Red Sea, nearly opposite Jedda. It occurs in commerce in subglobular tears, which are always much disintegrated, by reason of its brittleness, showing a conchoidal, glassy fracture. Large tears appear opaque, on account of numerous fissures. The fragments vary from nearly colourless to brownish and reddish-brown tints. Large quantities are imported from Alexandria and Suez, and it is not infrequently sold for medicinal use.

4. *Morocco, Mogador, or Brown Barbary.*—According to Hooker and Ball, the most recent authorities on the subject, this sort of Arabic gum is produced by *Acacia gummifera* (*Mimosa gummifera, Acacia coronillæfolia, Mimosa coronillæfolia, Sassa gummifera*), a scarcely-known plant of Morocco, occurring abundantly as a thorny bush in the lower region of S. and W. Morocco, according to the testimony of the natives, who call the plant *alk tlah.* The gum does not seem to be collected in the W. portion of its range in S. Morocco, but in Demnet, whence it is carried to Mogador. Possibly it is only in the hotter and drier regions of the interior that the gum is produced in quantities to be worth gathering. At any rate, the gum is yielded only during the hot, parching months of July and August, and increases according to the hotness of the weather and the sickly appearance of the tree, being least after a wet winter and in a mild summer. Some accounts suppose the Moroccan gum arabic to be derived from the same *Acacia* which is found in Senegal; but all the inquiries made by Consul R. Drummond Hay, for Hooker and Ball, agree that this plant, the *alk awarwhal* of the Arabs, is not found in Sus, no such tree existing either north or south of the Atlas Mountains, its gum being brought from Soudan, and of inferior quality to that of *A. gummifera.* It is further stated that this latter species grows chiefly in the provinces of Blad Hamar, Rahamma, and Sus. Previous writers, including Hanbury, ascribe the Moroccan and Fezzan gum to *A. nilotica* [*arabica*], the *ssant* or *sont*, which is said to range widely over Tropical Africa, as far as Senegambia, Mozambique, and Natal, and even to Sind, Gujrat, and Central India. The gum assumes the form of worm-like tears of moderate size, and of light dusky-brown tint.

5. *Cape.*—In the Cape Colony, the *doornboom, wittedoorn,* or *karródoorn* tree (*A. horrida* [*Karroo, capensis*]), the commonest tree of the S. African deserts, spontaneously yields a very large quantity of an amber-brown gum, somewhat dull and unclean, and incompletely soluble in water.

6. *E. Indian—Babul, Siris, Kheir, &c.*—All, or nearly all, the gum called "E. Indian" in commerce is African produce shipped to Europe viâ Aden and Bombay; but several Indian species of *Acacia* afford gums of more or less value, which are utilized locally, though unknown beyond the limits of the country where they grow. The *babul* kind is ascribed to *A. arabica*, and is produced in Bengal, Coromandel, and the Deccan. The gum is exuded abundantly in March–April, and occurs usually in rather large tears or portions of tears, of a more or less dark-brown colour, rather brittle, with a shining fracture, wholly soluble in water, forming a weak, dark-coloured mucilage; it is often mixed with impurities. The *kheir* gum is obtained from *A. catechu* (see Tannin—Catechu). It is in rounded tears, varying from the size of a pea to that of a small walnut, or in broken fragments; it is mostly of bright shades of dark-amber or mahogany-brown, rather friable, the tears being cracked, and of a grain resembling coarse brown sugar. The dark tears especially have a sweet flavour. The gum is readily soluble in water, giving a thin but strong mucilage of a deep brown-sherry colour. Selected samples of this gum were sent from Chanda for valuation in 1873; the report was "ordinary arabic, value 20-25*s.* a cwt." It is stated that the Chanda gum could be placed in the Bombay market at 5¼ *rupees* (10*s.* 6*d.*) a cwt.; and that by exercising some care and attention, quantities could be procured equal to the sample reported on. The *siris* gum is derived from *A. speciosa*; it is yielded in considerable quantity, and is valuable for many ordinary purposes. The quality seems to vary, some being described as equal to good *babul*, while other is considered inferior, being only partially soluble in water, and forming a kind of stiff jelly. The latter kind is in dull irregular tears, flavourless, and of a dark-brown colour; it is used for adulterating gum arabic (the imported article), and, under the name of *lera*, in printing gold- and silver-leaf patterns on calicoes. The gum does not seem to be collected or sold on an extensive scale. Other Indian *Acacia* gums are obtained from *A. modesta*, in the dry tracts between Saharunpore and Delhi: it is in little, curled, yellow pieces, quite soluble; from *A. odoratissima*, in Coromandel, the Concans, the Nilgiris, and Assam: shining rounded tears, liable to agglutinate, of dark-brown colour, resembling *babul*, flavourless, and quite soluble; from *A. ferruginea*, in the Circars and Courtallum: dark-brown shining fragments of large tears, moist, readily agglutinated and tenacious, soft, flavourless, and dissolving in water to a coloured mucilage; from *A. leucophlœa*, in Coromandel, S. Mahratta country, Sholapore, and Delhi; and from *A. sundra*, in the mountains of Coromandel, and the Sunderbunds.

7. *Australian or Wattle.*—Several Australian species of *Acacia* furnish gums bearing more or less general resemblance to the commercial gum arabic. Principal among them is the black or

green wattle-tree (*A. decurrens* [*mollissima, dealbata*]); next in importance are *A. pycnantha*, and *A. homalophylla*, besides *A. harpophylla* and *A. Bidwilli*. The Australian species are of much more rapid growth than the African, and the supply of gum might be rendered abundant. It has been exported for cotton-printing, adhesive, and other applications. It occurs in large hard tears, sticks, and lumps, of pale-yellow, amber, or reddish-brown colour, and transparent; it is quite soluble in water, forming a strongly-adhesive mucilage, which is less liable to crack when dry than that of some other kinds.

The trade in gums of the arabic family has no mean importance. The annual export of Senegal gum amounts to about 3,000,000 *kilo.* (of 2·2 lb.). Of Suakin gum, some thousands of bales reached Suez in 1879. Cape Colony exported 101,241 lb. in 1872. Morocco exported 5110 cwt. of gums of various kinds (including sandarach) in 1872, a quantity much below the average. The exports of unenumerated gum from Alexandretta in 1879 were:—14 tons, value 2240*l.*, to England; 20 tons, 3200*l.*, to France; 7 tons, 1120*l.*, to Italy; 9 tons, 1440*l.*, to Austria; 18 tons 1450*l.*, to Turkey; 22 tons, 1760*l.*, to Egypt; total, 90 tons, 11,210*l.* Bagdad, in 1878, exported 24 cwt. gum arabic, value 10*l.*, to India and Europe. The imports of gum arabic into the Bombay Presidency in 1872–3 were:—18 cwt. from Turkey, 136 from the African coast, 13,106 from the Red Sea, 927 from Aden, 165 from the Persian Gulf; total, 14,352 cwt.; the exports were:—4561 cwt. to the United Kingdom, 60 to France, 3 to Trieste, and 1 to the African coast; total, 4625 cwt. Trieste has long been a most important centre of the gum arabic trade. The imports here were 2,695,100 *kilo.* (of 2·2 lb.) in 1877, 2,726,300 in 1878, and 4,638,400 in 1879; the exports in the same years were 2,707,600, 2,796,400, and 3,080,900 *kilo.* respectively. The shipments to England alone in 1879 were 1586 tons. All the gum received at Trieste is classified into the following 32 grades:—

Name.	Mean Value per 220 lb.	Name.	Mean Value per 220 lb.
1. Arabic, white, 1*a*	299 –302*s.*	18. Arabic, crude, select, 5*g*	159½–161½*s.*
2. Ghizira, white, 1*b*	206 –208*s.*	19. Sennary and Ghizira, crude, granular, 5*h*	79 – 82*s.*
3. Arabic, pale-yellow, 2*a*	208 –210*s.*	20. Jedda, 6*a*	126 –128*s.*
4. Ghizira, pale-yellow, 2*b*	193 –195*s.*	21. Senegal, choice, 6*b*	116½–121*s.*
5. Arabic, yellow, 3*a*	168 –173*s.*	22. Senegal, crude, 6*c*	82 – 84*s.*
6. Ghizira, yellow, 3*b*	143 –144½*s.*	23. Arabic, crude, 7*a*	114 –117½*s.*
7. Arabic, superfine, choice, 4*a*	129½–151*s.*	24. Arabic, crude, without dust, 7*b*	131 –134½*s.*
8. Arabic, fine, 4*b*	120 –121*s.*	25. Arabic, crude, granular, 7*c*	134½–137¾*s.*
9. Ghizira, fine, 4*c*	108 –111*s.*	26. Sennary, crude, and Ghizira, 8*a*	79 – 80½*s.*
10. Arabic, medium, choice, 4*d*	114 –116*s.*	27. Sennary, crude, and Ghizira, without dust, 8*b*	79 –80½*s.*
11. Ghizira, medium, choice, 4*e*	80 – 84*s.*		
12. Arabic, granular, 5*a*	97½– 99*s.*	28. Sennary, crude, and Ghizira, granular, and without dust, 8*c*	79 – 80½*s.*
13. Arabic, granular, 5*b*	88 – 89*s.*		
14. Ghizira, granular, 5*c*	77½– 80½*s.*	29. Saukin, crude, 9	67½– 72½*s.*
15. Suakin Sennary, granular, 5*d*	73 – 77½*s.*	30. Senegal, genuine, crude, 10	117½–119½*s.*
16. Suakin, ordinary, granular, 5*e*	60½– 54*s.*	31. Damaged, 11, according to quality.	
17. Arabic, crude, granular, 5*f*	120 –121*s.*	32. Powdered, 12, according to quality.	

The imports of gum arabic into the United Kingdom were 49,305 cwt., 133,980*l.*, in 1876; 54,014 cwt., 167,503*l.*, in 1877; 59,147 cwt., 179,118*l.*, in 1878; 88,957 cwt., 256,677*l.*, in 1879; 75,397 cwt., 216,072*l.*, in 1880. The imports for 1880 were contributed as follows:—From Egypt, 51,543 cwt., 149,021*l.*; Austrian territories, 6555 cwt., 20,519*l.*; Aden, 5017 cwt., 14,669*l.*; Australia, 4657 cwt., 8962*l.*; other countries, 7625 cwt., 22,901*l.*; total, 75,397 cwt., 216,072*l.* Our imports from Austrian territories have been:—6502 cwt. in 1876, 5720 in 1877, 4411 in 1878; 6964 in 1879; from Egypt: 31,981 cwt. in 1876, 35,924 in 1877, 42,205 in 1878, 65,024 in 1879; from Morocco: 4893 cwt. in 1876, 4869 in 1877, 1459 in 1878, 2810 in 1879, 2401 in 1880; from the Cape: 3 cwt. in 1876, 26 in 1877, 45 in 1878, 32 in 1879, 23 in 1880; from S. Australia: 373 cwt. in 1876, 748 in 1877, 1172 in 1878, 4442 in 1879, 3908 in 1880. Our re-exports of gum arabic in 1880 were: 5725 cwt., 20,923*l.*, to the United States; 4689 cwt., 12,168*l.*, to Germany; 3793 cwt., 10,361*l.*, to Holland; 2562 cwt., 7373*l.*, to Australia; 2379 cwt., 5739*l.*, to Belgium; 2316 cwt., 5355*l.*, to Russia; 1991 cwt., 5719*l.*, to France; 3253 cwt., 9046*l.*, to other countries; total, 26,708 cwt., 76,684*l.*

The approximate London market values of the various kinds of gum included under "arabic" are as follows:—E. India: pale, fine, 2*l.*–3*l.* 10*s.* a cwt.; sorts, middling to fine, 1*l.* 15*s.*–2*l.* 15*s.*; garblings and siftings, 1*l.* 5*s.*–2*l.* Turkey: picked good to fine, 6*l.* 10*s.*–10*l.*; second and inferior, 2*l.* 10*s*–5*l.* 10*s.*; in sorts, 1*l.* 10*s.*–3*l.* 5*s.* Jedda and Talca: 1*l.* 4*s.*–2*l.* Barbary: brown, 2*l.*–3*l.* 5*s.* Australia: 1*l.* 5*s.*–2*l.* 10*s.* Senegal: 2*l.* 10*s.*–3*l.*

Asafœtida (Fr., *Asafœtida*; Ger., *Asafœtida*, *Asant, Stinkasant, Teufelsdreck*).—There are at least 3 distinct kinds of asafœtida:—(1) *Hingra* in local nomenclature, produced by *Narthex Asafœtida* [*Ferula Narthex*], and constituting the drug of European commerce; (2) *Kandahari-hing*, also obtained from *Narthex Asafœtida*, but only in minute quantity, and unknown outside of India; (3) *Hing*, afforded by *Ferula alliacea* [*Asafœtida*], and officinal in India, though scarcely known beyond it.

The relative geographical distribution of these two plants, or even the limits within which they thrive, are matters of considerable obscurity, travellers mostly alluding to them without reference to their botanical identification. Their range seems to extend from Persia and the Caspian region through Afghanistan into Tibet. According to Bellew, the *hing* plant grows wild on the sandy and gravelly plains that form the W. portion of Afghanistan. It is not under cultivation, but it is tended and watered by the Kakar Afghans wherever it is found. Indeed Wood observed that the asafœtida-growing districts around Sykan or Saigan were portioned out like corn-fields, and as carefully guarded. About the commencement of March, the leaves of the plant sprout afresh from the perennial root; and during the succeeding months of April and May, when the product is most plentiful, the whole plain country between Kandahar and Herat is occupied by the Kakars of the Bori Valley and the hills about the Bolan, who almost monopolize the collection and exportation of the gum-resin. The plant is said to grow in greatest abundance at Anardarra, in the Halmand (Helmund) district, though it is also scattered all over the W. portion of Afghanistan, and extends into the N. parts of Persia and Turkestan. Bellew saw the plant in great abundance beyond the Harut river, and on the plains of Birjand and Ghayn. It is also met with on the E. side of the Indus valley, in the Jhelam basin, and on the Upper Chenab. Col. Stewart (see Proc. R. Geog. Soc., Sept. 1881, pp. 521–2–4) speaks of asafœtida (species not stated) as being the only product of the desert country crossed by him between the spring of Chasma Shutaran and the village of Zangi Chah, both situated in Khorassan, on the S.-E. border of the Dasht-i-Kavir or Great Salt Desert. The district approximately comprises the land lying between 55° and 58° E. long., and 33° and 35° N. lat. The production here is very great. He remarks that the Persians know of no use for the drug.

The collection of the gum-resin is effected in the following manner:—About April–May, the frail, withered, and vaginated stem belonging to plants of the previous year (on roots at least 4 years old), as well as the cluster of fresh, green, sheathing leaves that may have sprouted before the withered portion has been blown away by the wind, is cut away at the junction with the top of the root. A trench about 6 in. wide and deep is cut in the earth immediately surrounding the root. In some instances, it would seem that the incising of the root follows at once; in others, a period of 40 days is allowed to elapse, during which, the soil is loosely returned to the trench, and the root is further protected from the solar heat by a coating of leaves and herbage, secured by a stone. The incising operation consists in making either several deep cuts across the upper portion of the root, or in removing very thin slices from it. In both cases, the wounded surface affords a milky exudation, which may be so sparse as to coagulate in tears upon the wound, or so plentiful as to escape into the trench around the root, and there solidify in lumps more or less contaminated with earthy and sandy particles. The yield from the first cutting is termed *shir* ("milk"), being more liquid than the subsequent product; it is much less esteemed, and is very largely (20–200 per cent.) adulterated with a soft earth, wheat-flour, or powdered gypsum, mainly perhaps to give it a portable consistence. The incisions are repeated at intervals of 3–4 days, extending to a fortnight if the flow warrants it. The exudation at this time assumes a thicker condition, and is known as *pispaz*. The wounding of the root is repeated at longer intervals during June, July, and even later, until the root is quite exhausted. After every incision, the protection of the root from the sun is very carefully attended to, otherwise the heat causes the root to wither, and stops the exudation. The quantity of the gum-resin afforded by each root varies from 1 oz. to 2 lb., much depending upon the development of the roots, whose size ranges between 1 in. and 6 in. in diameter. Bellew distinguishes two kinds of asafœtida plant, called respectively *kama-i-gawi* and *kama-i-anguza*; the former is grazed by cattle and used as a pot-herb, while only the latter affords the gum-resin.

It would seem that *hing*, the produce of *Ferula alliacea*, is obtained by taking thin slices from the crown of the root, together with the gum-resin which had collected upon them, until the root is exhausted. The slices are generally extremely thin, and form but a small proportion of the whole mass. To make the commercial article, the exhausted root is collected, cut up, and mixed with the gum-resin which has been obtained as described, by means of water. The drug reaches Bombay usually in skins weighing 100 lb. or more; occasionally also in boxes. The quality varies much, chiefly in the proportion of exhausted root. On arrival at Bombay, it frequently undergoes further adulteration with gum arabic, to effect which, the packages are broken up, the contents are moistened, and the added gum arabic is trodden well into the mass by men with naked feet upon a mat; the sophisticated drug is afterwards sewn up again in the skins to appear genuine. According to the 'Pharmacographia,' this article is called also *Abushahiri-hing*, from the fact of it its being imported from Abushir (Bunder Bushehr) and Bunder Abbas, on the Persian Gulf. The term *hira-hing* is applied to a liquid of treacly consistence often found in the centre of the packages of *Abushahiri-hing*, and which is squeezed out, and retailed at a high price. When dried, it becomes solid and translucent.

Kandahari-hing is obtained solely from the leaf-bud in the centre of the root-head of *Narthex Asafœtida*, by wounding with a sharp knife, and is generally mixed with numerous leaf-buds. It reaches Bombay in small quantities, sewn up in goat-skins, forming little oblong bales, with the hair outside. When first received, it is in moist flaky pieces and tears, from which a quantity of reddish-yellow oil separates on pressure; the gum-resin itself is of dull, reddish-yellow colour, soft and elastic, with an odour of garlic and caraway-oil. By keeping, it gradually hardens, becomes brittle, assumes a rich red-brown colour, and its odour becomes more alliaceous and like that of the commercial asafœtida. The price of this pure drug is much higher than that of the ordinary. For instance, at Kandahar 1 *man-i-tabriz* (about 3 lb.) of the former sells for 4–7 *rupees* (of 2*s.*), while the latter brings only 1½–3½. It is very much esteemed by the wealthy people of Central India, and is used by them as a condiment and in medicine. The quantity is very limited, and the article is not to be found in general commerce in Bombay.

Hingra, the asafœtida of European commerce, obtained from the root of *Narthex asafœtida*, reaches Bombay from both Persia and Afghanistan. That produced in the former country, mainly in the province of Laristan, and hence known locally as *anguze-i-Lari*, arrives at Bombay viâ Afghanistan and the Bolan Pass; it is often in a moist condition when received, containing opaque milky tears, sometimes 1–2 in. long, but soon hardens. The Afghan product, according to Dr. Dymock, goes by the Indus route, and generally arrives in a hard, dry condition, very fine samples being not uncommon. Only the very poorest classes in India will use this product, which is there officinally replaced by the much more powerful *hing*, and it is received almost exclusively for re-export to Europe.

The cultivation of all the asafœtida-yielding plants would appear to be a matter of the greatest simplicity under suitable conditions of soil and climate, and the subject is one that commends itself to the attention of planters in India, Australia, and Africa. The great centre of the trade in asafœtida is Bombay. The Indian imports of the drug from Persia range between 5000 and 7250 cwt. a year, of which, only about 1800 cwt. are re-exported. In 1872–3, Bombay Presidency imported 535,360 lb. of *hingra* from the Persian Gulf, and exported of the same kind, 348,480 lb. to foreign ports, and 48,958 lb. to other presidencies. The imports of *hing* in the same year were 345,072 lb. from the Persian Gulf, 448 lb. from Bengal Presidency, 896 lb. from Madras Presidency, and 30,688 lb. from Scinde; the exports of *hing* in the same year were 1218 lb. to foreign ports, and 147,349 lb. to other presidencies. The exports of asafœtida from the Persian Gulf ports in 1879 were valued as follows:—From Bushire, 12,000 *rupees* (of 2*s.*) to India; from Lingah, 7300 to India, and 300 to Muscat; from Bahrein, 75 to Koweit, Busrah, and Bagdad. Shanghai imported 37½ *piculs* (of 133⅓ lb.) of asafœtida from Hong Kong in 1879, of which, 10½ *piculs* were re-shipped to Chinese ports. The consumption of the gum-resin in England is comparatively trifling, and wholly medicinal (see Drugs, p. 793); on the Continent, it is in much more extensive pharmaceutical use, and is esteemed as a condiment; while in the East, including both Hindus and Mahomedans, it is much more important as a flavouring for pulse dishes than as physic.

The approximate London market value of asafœtida is 12–70*s.* a cwt. for common to fine.

It is quite possible that other species of *Ferula* occurring throughout Central Asia might or do contribute somewhat to the supply of the gum-resin, but actual information on this point is wanting.

Balata.—The gum known as balata is a product of the bullet- or bully-tree of Central and S. America, *Mimusops Balata* [*Sapota Mülleri*, *Achras Balata*]. This tree is found very abundantly in British, French, and Dutch Guiana, British Honduras, and Brazil, flourishing best on the river-banks. As a timber-tree, it was known to the earliest colonists, and its plentifully-secreted sweet milk has been used as food by the natives since time immemorial; but it was only in 1860 that experiment was made to introduce the concreted juice as a substitute for indiarubber in European industry. The first specimens were obtained from the lowlands of the swampy Canje river, and the success attending the experiments soon created a new article of commerce for Canje Creek. The supply seems still to be derived mainly from this locality, where the trees have a diameter of 6–30 in. and a height of 20–60 ft. to the lowest branches.

There would appear to be two species or varieties of the tree, one with an oval fruit giving a more ruddy milk. In French Guiana, where the tree occurs most numerously in the upper Marinoni, it bears the several names *balata rouge* or *franc*, *balata saignant*, *balata des Galibis*, and *boromé des Arrouages*. Several other *Sapotaceæ* are said to be called *balata* in Guiana and the Antilles.

The extraction of the milk is performed in the following manner. The coarse, woody, outer bark of the tree is first stripped off; the tree is then "tapped" by making a number of incisions with a cutlass, usually in an oblique direction, and extending as high up the trunk as the man's arm will reach, generally about 7 ft. Below the wounds, a ring of clay is wrapped around the tree, and serves to catch the escaping milk, which is then collected in calabashes or other non-metallic vessels. The quantity of milk thus obtained varies from 6 to 30 oz., which, when dried, gives ¾–1 lb. of solid balata. This process is not injurious to the trees, the incisions being filled up by new bark in the course of a year or two. A second method of securing the milk is to cut down the tree, and make circular cuts 1 in. broad at about 1 ft. apart throughout the whole length, placing a receptacle beneath each. An average tree will thus afford 5½–11 lb. of dry balata, as much as 45 lb. being sometimes obtained from large trees. The gum is less coloured in this case, but the tree is destroyed.

The crude gum rapidly hardens on exposure to the air, especially in the shade; in dry weather, 2–3 days suffice to give the surface the colour and consistence of leather. The slabs are turned occasionally till the whole mass is dry, and are then packed in leaves, or moulded into blocks by means of hot water. The sp. gr. of clean, dry, solid balata is 1·042. In many of its properties, it occupies an intermediate position between indiarubber and guttapercha, possessing the elasticity of the one and ductility of the other, without the intractability of the former or the brittleness of the latter, thus becoming under certain circumstances more valuable than either for industrial purposes. Heated to 49° (120° F.), it softens and may be welded, while it does not melt below 132° (270° F.). It is quite soluble in benzol and carbon bisulphide, in the cold; and in turpentine, chloroform, and petroleum, when heated; but is only partially soluble in anhydrous alcohol and ether. It is not acted upon by caustic alkalies, nor by hydrochloric acid; but is much affected by concentrated sulphuric and nitric acids. It vulcanizes readily. It was originally introduced exclusively as a manufacturing article, for insulating telegraph wires, and such purposes; but since it has become familiar in the United States, attention has been attracted to its excellent qualities as a masticatory, and factories have been established in New York, New England, Ohio, Illinois, and Tennessee, for its preparation as a chewing material, the consumption in this way amounting to 50 tons annually. Despite the industrial value of balata, its employment is decreasing, mainly owing to the difficulty of procuring supplies, by reason of the unhealthiness of the occupation. Systematic cultivation of the tree would greatly obviate this, but has not yet been attempted. Berbice exported 20,000 lb. in 1865. (See Chicle, p. 1639.)

Balm of Gilead, Mecca Balsam, or Opobalsamum.—The *Balsamodendron gileadense* [*Opobalsamum*], a native of Arabia and Abyssinia, possesses a grateful fragrance in every part, due to the presence of an oleo-resin, which exudes when incisions are made in the bark. This product was regarded with most exaggerated esteem in biblical and classical times, and still has a boundless repute in the East, but is almost unknown in European commerce. An allied or identical balsam is afforded by an Indian species, and equally valued. This latter has a syrupy consistence, and is limpid and yellow; it thickens and hardens with age. The pure article is almost completely soluble in alcohol, but it is nearly always adulterated with turpentine, olive-oil, or wax. According to Wiesner, the little balm which reaches Europe is obtained by boiling the twigs of the plant in water, and is very much inferior to the article in Oriental use.

Other *Balsamodendron* products are described under Bdellium (below) and Myrrh (p. 1674).

Bdellium.—The myrrh-like gum-resin known as "bdellium" is of three kinds, termed respectively Indian, African, and opaque, all afforded by species of *Balsamodendron*.

1. *Indian Bdellium, Googul, or Mukul.*—This is a product of two or more species, chiefly *B. Roxburghii* [*agallocha*] of Silhet and Assam, and *B. Mukul* of Sind. The former is a very hardy plant, and readily propagated by cuttings. The bark is scarified, and the liquid exudation is placed in bottles, where it clarifies by age and exposure to the sun. This is by far the less important of the two species. *B. Mukul* is a native of Arabia, and is found on rocky ground throughout Sind, at Disa in Marwar, and in Beluchistan. Both the shrub and its gum-resin are called *googul* or *guggur* by the Hill Beluchis. The gum-resin is collected by them in the cold season, by incising the tree with a knife, and allowing the exudation to fall to the ground, by which it acquires the dirty, impure state commonly exhibited by that met with in the native shops. The yield amounts to ½–1 *seer* (of 2·2 lb.). The best is clear, pure, brilliant, viscous, adhesive, soft, yellow, bitterish, and of fragrant odour. By age, it increases in bitterness, darkens in colour, and becomes hard and dry. It is largely soluble in water. It is brought into the bazars of Hyderabad and Karachi, where it sells for 2 *rupees* (4*s.*) a *maund* (80 lb). Locally it is used medicinally, both for men and horses, but chiefly as incense for burning in the temples, and (in solution) as a strengthening ingredient for mortar. The article is sometimes sold for and considered as an inferior kind of myrrh. Portions of the birch-like bark of the tree are often found adhering to it. A third species that may be mentioned is *B. pubescens*, inhabiting Beluchistan, and the hills separating that province from Sind, probably also Afghanistan, and reaching its S. limit about Karachi. It is called *bayee* by the Hill Beluchis, but is not availed of by them. In the cold season, it exudes a small quantity of a brittle gum, almost completely soluble in water, but devoid of odour and flavour, though the young shoots and buds are remarkably fragrant when bruised. The imports of bdellium into the Bombay Presidency in 1872–3 were:—200 cwt. from the Red Sea, 7 from Aden, 70 from the Persian Gulf, and 426 from Sind; total, 703 cwt.

The *googul* of the Coromandel coast is obtained from *Boswellia glabra*, that of Khandeish from *Boswellia serrata*.

2. *African Bdellium.*—The African kind is produced by *B.* [*Heudelotia*] *africanum*, a shrub

growing in S. Arabia, Abyssinia, Mozambique, and throughout the whole of tropical Africa to Senegambia. The bulk of the gum-resin comes from Senegal, where its collection is not separately conducted, but is performed by the seekers after gum arabic, the produce being mixed with the latter gum. This does not occur through confusion of the plants yielding the two articles, but rather to increase the harvest of gum arabic. Classification takes place when the mass reaches Bordeaux. African bdellium is hard, translucent in thin layers, red by transmitted light, with a bitter flavour, and a slight aromatic odour of black pepper; its fracture is of dull, slaty hue, the margins having a powdery resinous appearance. Triturated with water, it forms an emulsion. R. H. Parker states that on standing, it gives a nearly bright mucilage, with a copious brown sediment, the mucilage indicating presence of a considerable proportion of gum allied to tragacanth. This authority gives the composition of African bdellium as—15·4 per cent. soluble in alcohol (by difference), 33·2 gum soluble in water, 37·8 gum insoluble in water, 13·6 moisture. Other analyses differ extremely. There are no statistics concerning the trade in African bdellium. It appears to be employed only in Continental pharmacy.

3. *Opaque Bdellium.*—This is attributed by Parker to *B. Playfairii*, which is stated by Hanbury to produce *hotai* gum, a whiter and more brittle substance, used by the Arabs for washing their hair. It is a very hard, ochre-yellow coloured, opaque gum-resin, with but slight odour, and a bitter flavour. The tears of this substance frequently have portions of papery bark attached to their surface. Triturated with water, it forms a very good cream-coloured emulsion. Cold absolute alcohol dissolves about 50 per cent.; a considerable portion of the residue resembles bassorine. The composition is given as—47·42 per cent. soluble in alcohol (by difference), 30·01 gum soluble in water, 11·07 gum insoluble in water, 11·50 water. It occurs among the "spurious gums" imported with myrrh.

Other *Balsamodendron* products are described under Balm of Gilead and Myrrh (pp. 1636, 1674).

Benzoin or Benjamin (Fr., *Benjoin*; Ger., *Benzoë*).—The English commercial name of this resin, "benjamin," is a vulgar corruption of "benzoin," itself derived from the corrupted form *banjawi* of the old Arabic name *lubán jáwi*, or "Java frankincense." The form "benzoin" is likewise applied to a product ($C_{14}H_{12}O_2$) of the treatment of bitter-almond-oil with alcoholic solution of potash.

The resin benzoin is obtained partly from *Styrax Benzoin*, a tree indigenous to or introduced into Sumatra, Java, Borneo, Siam, and Cochin China. There are reasons for supposing that *S. subdenticulata*, of W. Sumatra, and *S. Finlaysoniana* contribute somewhat to the several qualities of the resin, but nothing definite is known on the subject. Almost equal ignorance prevails as to the distribution of the benzoin-yielding tree or trees. Crawfurd's statement that benzoin is collected on the N. coast of Borneo, in the Brunei district, is negatived by its absence from all official returns of the trade of the island. The only two countries which can with certainty be said to afford the resin are Sumatra and Siam.

The tree yielding Sumatra benzoin, called *kaminian* by the Malays, is found in the N. and E. portions of the island, especially in the Batta country, north of the equator, but not in the Achinese territory immediately beyond. It is also met with in some abundance in the highlands of Palembang, in the south, where its product is likewise collected, though said by Marsden to be in small quantity, and of dark and inferior quality. The resin brought from the interior is mostly from wild trees, growing on the mountain spurs at 300–1000 ft. But in the coast regions, considerable care and attention are devoted to the cultivation of the tree, in regular plantations, or on the edges of the rice-fields. The trees are raised from seed, and grow rapidly. The seedlings are kept clear of other plants, and generally attain a diameter of 6–8 in. at the 7th year. The first incisions (longitudinal or oblique) are now made in the bark, whence exudes a thick, whitish, resinous juice, which soon concretes in the air, and may be scraped off. The best product, locally termed "head," is that which is obtained from the incisions of the first 3 years; it contains more of the yellowish-white tears, and is softer and more fragrant. During the next 7–9 years, the exudation becomes more reddish-yellow or brown, and is known as "belly" or 2nds. The yield averages 3 lb. annually. Finally, the exhausted tree is cut down, split in pieces, and scraped to afford the 3rd quality, or "foot," which is dark-coloured, hard, and mixed with much wood-parings and other impurities. The product is carried down to the ports in large cakes (*tampangs*) covered with matting. It there undergoes preparation for market. According to Marsden, the "head" or 1sts is divided into "Europe" and "India," the former only coming into Western commerce, while the latter, with the "belly" and "foot" (2nds and 3rds), goes to Arabia, Persia, India, and Malaysia, to be burnt as an incense in temples and as a deodorizer in dwellings. The "Europe-head" is softened for packing in cubical, wooden chests, sun-heat sufficing for the finer grades, while boiling water effects the same purpose with the coarser qualities.

Less is known regarding the origin and production of Siam benzoin. Its distinct dissimilarity from the Sumatra article would infer its derivation from another species of *Styrax*, but botanists are ignorant of the facts. The distribution of the plant is also a matter of great uncertainty. Moore states that it is found only in the N. provinces of Siam, and in Laos. A French expedition in 1866–8 reported the production of the resin in the cassia-yielding forests on the E. bank of the Mekong river, N. lat. 19°. Some of the Siam benzoin is obtained by gashing the bark all over, and leaving the exuding resin to collect and harden between the bark and the wood, the former being then stripped off; but all is not thus procured. The product is conveyed in small baskets on bullock-back to the Menam river, and thus floated down to Bangkok, where it is packed in cubical boxes exactly like the Sumatra kind. It is said to be exclusively of the "head" quality.

The benzoin received into British commerce is primarily distinguished as "Siam" and "Sumatra," each sort exhibiting variety of purity and appearance. The best of the former consists of an agglutinated mass of flattened, opaque, milk-like tears of white resin; oftener it reveals white, almond-like fragments embedded in an amber-brown translucent matrix, and the white tears are occasionally very minute, or almost altogether wanting. These latter have a stratified structure, including translucent layers. The mass is brittle, with a vanilla-like odour, but little flavour, and is readily softened by heat [fusing-point, 75° (167° F.)]. The Sumatra article has a generally greyer tint than the Siam, but when good, exhibits many opaque tears in a translucent greyish-brown body, the tears diminishing as the quality declines. The odour is less powerful and pleasant than that of the preceding. The tears melt at 85° (185° F.); the greyish-brown mass, at 95° (203° F.). Both kinds contain an admixture of fragments of wood, bark, and other foreign matters. There also appears in the London market at intervals a variety of benzoin, locally distinguished as "Penang or storax-smelling benjamin," having a highly fragrant odour, quite distinct from the ordinary kinds. The source of this is a matter of obscurity.

The chief mart for benzoin is Singapore. The imports here in 1871 were 6185 cwt. from Sumatra, and 405 cwt. from Siam; the exports in 1877 were only 1871 *piculs* (2227 cwt.). Penang, in 1871, received 4959 cwt. from Sumatra for re-export. Padang (Sumatra) exported 4302 *piculs* (5122 cwt.) in 1870, and 4064 *piculs* (4838 cwt.) in 1871. Bombay imported 4902 cwt. from the Straits Settlements in 1872–3; the exports in the same year were:—1903 cwt. to the United Kingdom, 198 to the Persian Gulf, 134 to African coast, 37 to Aden, 26 to the Red Sea, and minor quantities to Turkey, Mekran, France, &c.

The principal application of the resin is in perfumery and as an incense for church use (see Perfumes). Lesser quantities of it are used in various compositions to prevent rancidity in fats; it is also the source of benzoic acid, employed in perfumery and medicine, and is an ingredient of black sticking-plaister, and the base of Friars'-balsam. The approximate London market values of benzoin are as follows:—Siam, 2nd and 1st, 10–70*l.* a cwt.; Sumatra, 2nd and 1st, 5–15*l.*; 3rd, 2*l.*–4*l.* 15*s.*

Other products which may be mentioned here are the aromatic resins afforded by *Terminalia Benzoin* in India, and by *T. mauritiana* in Mauritius. The former is esteemed as a cosmetic, and the latter as incense, but neither appears in commerce beyond the immediate neighbourhood of the locality producing it. Probably some misapprehension underlies the statement that benzoin, obtained from *Styrax Benzoin*, has recently been sent in some quantity from the Brazilian province of Bahia.

Cadjii or Cashew (Fr., *Gomme d'acajou*; Ger., *Anacardium-gummi*).—This gum is obtained by wounding the trunk and branches of *Anacardium occidentale*, the tree affording cashew-nuts (see Nuts, p. 1352), and two kinds of oil (see Oils, p. 1379). The gum is collected in Martinique, Guadaloupe, Brazil, India, and Burma. In India, the incisions are made while the sap is rising. The gum usually occurs in elongated stalactitic pieces, or cylindrical tears, varying in colour from dirty-white to dirty-brown, the S. American being mostly topaz-yellow to brownish-red. It is sub-astringent, and highly unpalatable to insects. It consists principally of arabine and dextrine, both soluble in water, with a minor insoluble portion, probably bassorine. It forms a strong, yellowish mucilage with water. In S. America, it is largely used by book-binders; it is occasionally imported from that continent into this country, and possesses the same commercial value as the common and inferior sorts of Arabic and Senegal gums (see pp. 1630–1).

Camphor.—See Camphor, pp. 571–8.

Canada Balsam.—See Turpentine—Canadian, p. 1686.

Chagual or Maguey.—This gum is afforded by one or more S. American species of *Puya* [*Pourretia*]; *P. coarctata* of Chili, and *P. lanuginosa* of Peru, have been more particularly indicated as its sources. The exudation is said to be caused by punctures from a caterpillar (*Castnia elegans*), the gum hardening on the stem, and occurring in commerce in cylindrical pieces, whose inner surface generally exhibits fragments of parenchyma, and whose size implies a diameter of ¾-1¼ in. in the stems on which the gum has concreted. The fracture of the gum is conchoidal; its colour, topaz-yellow; its hardness, about the same as gum arabic; its tenacity, somewhat less than tragacanth; its density, when air-dry, 1·866. It is exceedingly rich in bassorine, only about 16 per cent. of it being soluble in water.

Cherry (Fr., *Gomme du pays*; Ger., *Kirschgummi*).—"Cherry-gum" is a term applied very indefinitely to the gummy exudations of cherry, plum, apricot, almond, and other trees, included in the genera *Prunus*, *Cerasus*, and *Amygdalus*. The secretion of the gum takes place in the wood of these trees, as well as in the bark. The masses of this gum are usually sub-globular or reniform, and often of considerable size. The fracture is conchoidal and strongly lustrous; the colour ranges from pale-yellow to brown, the plum-gum being generally light while the cherry-gum is darker; the gum is brittle, but less easily pulverized than the *Acacia*-gums; its flavour varies from sweet to astringent, but is always insipid. The solubility in water is not complete in any variety. The peach and almond kinds are least soluble, containing but little arabine; cherry contains about 52 per cent. arabine, and 35 cerasine. These gums are not commercial articles in England, nor in Germany of late years, but continue to have some importance in French industry, those mostly employed being from cherry and plum trees.

Chicle, Mexican Gum, or Sapota.—Much uncertainty surrounds this product. It has been known in America for some time, and extensively used as a masticatory, in the same manner as balata (see p. 1635), which it closely resembles, if, indeed, it be not identical in origin. All botanists are agreed in referring it to a Sapotaceous plant, some to *Mimusops Balata* itself. The country of its production is Mexico. The differences which it exhibits in comparison with balata may easily prove to be exclusively due to the mode of preparation for market. Analyses by Prochazka and Endemann (see Bibliography, p. 1695) gave:—75 per cent. resin, 10 arabine, 9 oxalate of lime, 5 sugar, 0·5 soluble inorganic salts; this indicates it to be a product simply of direct evaporation of the milk of the plant.

Chironji.—The common Indian tree *Buchanania latifolia*, whose fruits afford an oil (see Oils, p. 1383), yields a considerable quantity of an arabic-like gum, 5 lb. being obtainable from good specimens. It is but little availed of, though the reports of experts place it in the same category with inferior *Acacia*-gums, and consider it capable of replacing these in the dressing of textiles. It is mostly soluble in water, forming a colourless mucilage equal in strength to ordinary commercial gum arabic; but it also contains some insoluble bassorine.

The cut bark of the tree is likewise said to afford a natural varnish.

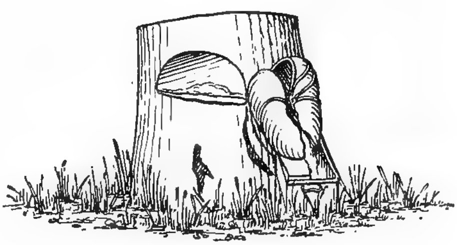
Coco-nut (Fr., *Gomme de Coco*; Ger., *Cocosgummi*).—From the bark of the coco-nut-palm, so well known for its fruit (see Nuts, pp. 1353–7) and for its oil (see Oils, pp. 1383–4), is obtained a gum termed *haari tapan* by the natives of Tahiti. It forms stalactitic masses, of red-brown to hyacinth-red colour, translucent to transparent, sp. gr. 1·45–1·57, of arabic-like hardness, and tragacanth-like tenacity, and containing 70–90 per cent. of bassorine.

Colophony.—See Rosin, p. 1680.

Copaiba, Copaiva, or Capivi (Fr., *Baume ou óleorésine de Copahu*; Ger., *Copaivabalsam*).—This balsam or oleo-resin is afforded by several forest trees belonging to the genus *Copaifera* growing in the warm portions of S. America, in Central America, and in the W. Indies. No information exists as to the relative degrees in which the various species contribute to the commercial supplies of the balsam, but the following are accredited with its production:—(1) *C. officinalis* [*Jacquini*], in the hot coast region of New Granada (Colombia) as far north as Panama, in Venezuela, and in Trinidad Island; (2) *C. guianensis* [*bijuga*], in French and Dutch Guiana, and on the Rio Negro between Manaos and Barcellos; (3) *C. coriacea* [*cordifolia*], in the dry woods (*caatingas*) of the Brazilian provinces of Bahia and Piauhy; (4) *C. Langsdorffii* [*nitida, Sellowii, Jussieui, glabra, laxa*], growing as a tree on dry *campos*, *caatingas*, and other places in the Brazilian provinces of S. Paulo, Minas Geraes, Goyaz, Mato Grosso, Bahia, and Ceara, and yielding an abundance of balsam; (5) *C. multijuga*, specially producing the Para balsam. In all these trees, resiniferous ducts, sometimes above 1 in. diam., traverse the whole stem, and occasionally become so distended with the balsam as to burst the tree asunder. Karsten attributes the origin of the balsam to a transformation of the cell-walls in the parenchyma surrounding the ducts.

The process of collecting the *copaiba blanca* or "white copaiba" of Para is described at length by Robert Cross. Formerly the tree might be seen growing in readily-accessible places, but it has now become comparatively rare, so that the collectors require to make journeys of several weeks in canoes up the Amazon tributaries, and suffer great hardship in the undertaking. The trees occur in the dense, lofty forest, on an extremely fertile soil, composed of soft white sand and vegetable mould, undulating, and watered by streams, but some 50 ft. above the level of the *gapos* or tidal floods. A successful copaiba-tree tapper must be a skilful axeman. A cavity is cut in the trunk, not much broader than the axe, but large enough to enable the workman to vary the course to the heart of the tree in such a way as not to miss the "vein" or channel, usually met with near the centre, from which the balsam flows. The floor of the cavity is neatly cut with a gentle upward slope, and should also decline to one side, so that the issuing balsam may run in a body till it reaches the outer edge. Below the cavity, a pointed piece of bark is cut and raised, which, enveloped with a leaf, serves as a spout for conveying the balsam from the tree to a tin vessel, as shown in Fig. 1170. The cavity is cut at about 2 ft. from the ground. The first 4–5 in. of the wood is white, after which it changes to a purplish-red throughout the whole interior. When abundant, the balsam flows out in a stream, full of hundreds of little, white, pearly bubbles. At times, the flow stops during several minutes, when a singular gurgling noise is made, and a fresh rush of balsam takes place. At the height of the exudation, the rate cannot be less than 1 pint a minute. The chips and the surfaces of the cavity are bedewed with drops of balsam, showing its existence throughout the wood; the bark is quite devoid of it. Though balsam escapes from the trunk even for a month after the tapping, the usual plan is n t to let the receptacle remain for more than 2–3 hours. Occasionally large trees afford no balsam, the cause of which has not been ascertained. Trees in good condition will sometimes give 4 *potos* (10½ gal.) of balsam, and a collector with plenty of tin receptacles where trees are abundant may collect 5*l.* worth daily. The receptacles employed are of almost all descriptions, empty petroleum-cans being preferred.

1170.



The balsam is gathered by the Indians on the banks of the Orinoco and its upper affluents, and taken to Ciudad Bolivar (Angostura) for shipment, some of this balsam reaching Europe by way of Trinidad. It is more largely obtained on the tributaries of the Caisquiari and Rio Negro (the Siapa, Içanna, Uaupés), and the N. influents of the Amazon (the Trombetas and Nhamundá), and is sent down to Para. In S. Venezuela, the balsam is known as *aceite de palo* ("wood-oil"), the term *balsamo* being reserved for "sassafras-oil" from *Nectandra sp.* The balsam exported from Maracaibo is produced by *C. officinalis*, the *canime* of the natives. The exportation of the balsam takes place chiefly from Para, Maranham, Rio de Janeiro, Demerara, Ciudad Bolivar, Trinidad, Maracaibo, Savanilla, and Cartagena. In 1875, the shipments from Savanilla were 10,150 *kilo.*, from Para, 65,243 *kilo.*, and from Ciudad Bolivar, 99,800 lb.; the exports to New York from Ciudad Bolivar were 4165 lb. in 1878, and 1378½ lb. in 1879. Maracaibo, in 1880, exported 15,758 gal., 7474½ dol. (of 4*s.* 2*d.*). The balsam often reaches England by way of New York and Havre.

The balsams from Para, Maranham, Maracaibo, and the W. Indies are considered distinct, and are readily distinguished by experienced dealers. The first is of much less firm consistence than the second and third, and the W. Indian is opalescent, and usually deemed inferior, though probably on insufficient grounds. These differences are ascribed to variety of origin, and to oxidation and the loss of volatile constituents by exposure. The general characteristics of copaiba balsam are a more or less viscous fluid; of pale-yellow to light golden-brown colour; peculiar, aromatic, not unpleasant odour; persistent, acrid, bitter flavour; commonly transparent, sometimes opalescent; consisting of a resin held in solution by an essential oil, the latter forming 30–80 per cent.; of sp. gr. 0·940–0·993, according to the proportion of the oil; and mostly soluble in all proportions in absolute alcohol, acetone, and carbon bisulphide, in an equal volume of benzol, and in several volumes of alcohol at 0·830 sp. gr.

The balsam is very largely adulterated with castor-oil, turpentine, and other fixed and volatile oils, to which it readily lends itself by its inconstant character; it is extensively replaced by gurjun balsam here, and by the oleo-resin of *Hardwickia pinnata* in India, which are equally effective drugs. No reliable general test has yet been discovered for copaiba; but a few special tests may be mentioned. Treatment of the suspected mass with 1–4 parts petroleum-benzine will give dense floccules with 4 parts of turpentine present; and treatment with 10–12 parts of the benzine will cause a separation of even 10 per cent. of castor-oil. Most volatile oils would be detected by their ready solution in alcohol. A distinguishing test for copaiba, gurjun, and *Hardwickia* is:—Shake up 1 drop of the balsam with 19 of carbon bisulphide, add 1 drop of nitro-sulphuric acid (equal parts concentrated), and agitate: copaiba shows faint reddish-brown, with deposit of resin on the sides of the tube; gurjun, intense purplish-red, soon becoming violet; *Hardwickia*, no alteration from its pale greenish-yellow. This test will reveal 12½ per cent. of gurjun in copaiba.

The uses of copaiba are essentially medicinal (see Drugs, p. 809).

The cultivation of copaiba trees in India is advocated by Cross, who brought seeds from Brazil with that object. The site should be the best dry loam, suitable for cane or coffee; wet land is quite unfitted. The climate should be such as that enjoyed by the Para indiarubber, with which it is often naturally associated. Returns from the cultivation would be realized in about the same time as from oak plantations; a few hundred trees on an estate would much enhance its value.

See also Gurjun, p. 1651; Hardwickia, p. 1654.

Copal and Animi (Fr., *Copal, Anime*; Ger., *Kopalharz, Flussharz, Animegummi*).—The term "copal" is frequently used in a generic sense, embracing a number of resins of widely different origin. It will here be restricted to the fossil and recent copals of continental and insular Africa;

for the other kinds, readers are referred to their distinct headings—Dammar, Jutahy-seca, Kauri, and Piney.

The resin known as Bombay, E. Indian, or Zanzibar copal or animi, is a product of E. Africa, chiefly the neighbourhood of Zanzibar. It is of two kinds, fossil and recent. The exact genus and species of the tree yielding the former must remain a matter of doubt; the latter is attributed to *Trachylobium mossambicense* [*Hornemannianum*], a tree which is sometimes grouped with the very closely allied *Hymenæa spp.*, one or more of which yields a similar product in S. America (see Jutahy-seca). According to Burton, the copal-tree is called *shajar el sandarûs* by the Arabs, *msandarusi* by the Wasawahili, and *mnángû* by the Wazaramo and other maritime races. It still lingers on the island and mainland of Zanzibar, and was observed by him at Monibosa, Saadani, Muhonyera, and Mzegero of Uzamaro, and was heard of at Bagarmoyo, Mbuamaji, and Kilwa. The tree is said to be abundant in the woods adjoining the inner side of the wilderness in Usambara. It grows throughout the Uzamaro (Wazamaro) country much further south, and is by no means confined to the sea-coast, but is even more abundant inland beyond the first coast-ridge. It ceases towards the interior as soon as the limestone formation makes its appearance.

The present limits of the distribution of living copaliferous trees by no means prescribe the area of the extinct forests which have been the source of the fossil copal. This is "crowed" or dug up by the coast clans and the barbarians of the maritime region. In places, it is found when sinking piles for huts; and at times, it is picked up in spots overflowed by the high tides. Burton says that the E. African seaboard, from Ras Gomani in S. lat. 3° to Ras Delgado in 10° 41′, with a medium depth of 30 miles, may be called the "copal coast," every part contributing more or less to the commercial supply. He affirms that even a section of this line, from the mouth of the Pangani River to Ngao (Monghou), would, if properly exploited, suffice for all needs. The fossil resin is a great staple of the district traversed by the newly-made road from Dar-es-Salaam, through the Wazamaro country. It exists, even in the richest diggings, only in patches, as though it had been produced by isolated trees. The natives work it nowhere systematically; they sink numerous test-holes and work those only which alight immediately upon the resin, abandoning many where diligent search would probably be remunerative. The resin usually occurs in red sandy soil; according to the Arabs, the redder the soil the better is the copal. The surface of the copal ground is generally a thin coat of white sand, covering a dark, fertile humus, the vestiges of decayed vegetation, varying from a few in. to 1½ ft. in depth. In Zanzibar Island, the subsoil is a stiff blue clay; here the copal is found in the vegetable soil overlying the clay. At Saadani, the pits are about 3 ft. deep in humus and red sandy earth; the product is not esteemed, despite the redness of the soil.

The resin is called *sandarus* by the Arabs and Hindus, *sandarusi* by the Wasawahili, and *wezi* by the Wanyam. It is distinguished as of two kinds by the Arabs and Africans. The new, recent, "tree," or "raw" copal (Fr., *Copal vert*) is called *sandarusiza miti*, or more generally *chakazi*, commonly corrupted to "jackass." This is either picked from the tree, or is found, as in Zanzibar Island, embedded at a shallow depth in the loose soil, where it has not remained long enough to undergo any change. The living trees are of large size, averaging 20–25 ft. to the first branches, and 3–5 ft. in girth. The trunk is dotted with exudations of the raw resin, and, between the bark and the wood, are frequent secretions of the resin in a liquid form. Wherever an injury has been inflicted on the tree, there an accumulation of resin will be found; when the exudation is large, it falls off and becomes covered by the dusty soil. All parts of the tree are impregnated with the resin, even extending to the fruit-pods, which contain numerous little warts or verrucosities of clear, colourless resin, covered by a thin epidermis. The *chakazi* copal is a soft mass, of smoky appearance and low value. It is sent to Bombay for the Indian and Chinese markets, where it is used for making an inferior varnish.

The true or "ripe" copal, the *sandarusi* proper, is exclusively fossil. Dr. Kirk attributes it to the same species as now afford *chakazi*. It is certainly of vegetable origin. The regular and persistent indentations and elevations of the surface, to which the term "goose-skin" has been applied, have led to the supposition that the resin escaped in a liquid or semi-liquid state, and took impressions from the sand in which it was deposited. This view is doubly erroneous. The impressions are due, not to sand, but to the structure of the cellular tissue of the tree; and their occurrence is accounted for by the fact that the secretion of the resin increases with the decay of the tree, and is much hastened by the attacks of ants and other destructive influences, thus it is chiefly formed in masses within the tree itself, and naturally takes impressions from the tissue of the surrounding wood. This occurs with the existing trees. After the complete decay and destruction of the trees, the imperishable lumps of resin have become buried in the sands which have encroached upon the fertile soil formerly occupied by the forest. The fossil resin when first dug up has no trace of the goose-skin upon it. It is hidden by the outer layer of the resin, which has undergone oxidation or some molecular change during its long burial; on removing this outer layer by an alkaline solution and sun-drying, the goose-skin becomes apparent.

The native method of collecting the fossil resin is to "crow" a hole about 6 in. diam. with a pointed stick, and scrape out the loosened earth by the hand as far as the arm will reach. Each man could easily gather 10–12 lb. daily, but the average is about 1 lb. The digging is carried on only during the *kossi*, or rainy monsoon; during the dry season, the hardness of the ground is too great for the native implements to cope with, and the resin is said to be at that time very brittle and covered with sand. The collectors do not hesitate to add much of the inferior *chakazi* to the *sandarusi* when opportunity arises. The copal gathered in Zanzibar Island is entirely *chakazi*. That of Saadani is dull-white, and considered little better than *chakazi*. That obtained on the line inland from Bagamoyo and Kaole, as far as Mubonyera, though not first-rate, is much superior to that from about Saadani. Good copal is dug in the vicinity of Mbuamaji, and the diggings are said to extend for six marches inland. The Wadenkereko, a wild tribe mixed with and stretching S. of the Wazaramo, at two days' journey from the sea, supply a mixed quality, oftener white than red; the best is procured from Hunda and the adjacent districts. The banks of the Rufiji River, especially the N. district of Wandé, supply the finest and best copal; it is dug by the Wawande tribe, who either carry it to Kikunya and other ports, or sell it to travelling hucksters. In the vicinity of Kilwa, 4 marches inland, copal is dug by the Mandandu and other tribes. The produce of Ngao (Monghou) and the Lindi creek is much cheaper than that of Kilwa, being of variable quality, mostly a dull-white *chakazi*. The island of Madagascar is said to produce both *chakazi* and *sandarusi* identical with those of the mainland; but little is known of the method of collecting, or of the precise quality. The species is called *T. verrucosum*.

At the end of the rainy season, the copal is usually carried ungarbled to Zanzibar. Hence, after being sifted and freed from foreign matters, it is sent by the Banyan retailer to the Indian market, or sold to the foreign merchant. It is usual also to effect the "cleaning" here, though this is also done at Bombay, in some European ports, and notably at Salem, in Massachusetts. It is performed in the following manner:—The resin is first washed in a dilute alkaline ley, by which it loses some 20–37 per cent. of its bulk; it is then sun-dried for some hours, and subjected to a brushing sufficiently hard to remove the outer coat, but not to injure the goose-skin. The dark "eyes" where the dirt has sunk deep are picked out by an iron tool. The next step is garbling, which is done with careful regard to colour and size, and requires great experience. As a rule, the clear and semi-transparent pieces are the best; then follow the numerous and almost imperceptible grades of dull-white, lemon-yellow, amber-yellow, rhubarb-yellow, bright-red, dull-red, blackish, and grass-green. In size, the pieces vary from that of small pebbles to 2–3 oz.; they have been known to weigh 5 and even 35 lb. Finally, the gum is put into boxes for export. The dust, of which perhaps 30 lb. daily is brushed off by each workman, is termed "sand," and cast away as of no value; it is probably genuine resin, and of some worth.

The commerce in E. African copal is extensive. Zanzibar exports some 800,000–1,200,000 lb. annually, of which, 150,000 lb. goes to Hamburg, and about 2 lacs' (say 20,000*l.*) worth to Bombay. The Bombay imports in 1872–3 were 966 cwt. from the African coast; the exports were 312 cwt. to the United Kingdom, besides 48 cwt. chiefly to the Persian Gulf, Straits Settlements, and China, and 211 cwt. to the other presidencies of India. The exports of copal in British ships from the E. coast of Madagascar in 1872 were valued at 3466*l.*

On the W. coast of Africa, which is still richer in copal than the S.-E. coast, this resin is dug over a coast length exceeding 700 geogr. miles, between lats. 8° N. and 14° S. The copal is here found in a superficial stratum of marl, sand, and clay, at a depth varying up to 10 ft. The most important copal districts of W. Africa are Sierra Leone (N. part), Accra, Benin, Gaboon, Loango, Congo, Angola, and Benguela (S. part). Of the Angola product, Monteiro says that it comes almost entirely from the Mossulo country, though it exists further north, as at Mangue Grande.

The botanical sources of W. African copal are scarcely determined with certainty. Daniell attributes the Sierra Leone article to *Guibourtia copallifera*, and perhaps some other species; but Welwitsch is unable to state positively the origin of the copal of Angola and Benguela. The W. African copal, like that of the S.-E. coast, occurs as a recent fossil. Its existence in the most recent formations, and the water-rolled form of the fragments of Sierra Leone copal found between the rivers Pongas and Malaenzi, render it probable that the trees which afforded, and perhaps still afford, copal do not belong to the coast flora, but to the interior, whence the resin has been transported by the rains and rivers. Monteiro says that, according to native accounts, the Angola copal is found below the surface of a highly ferruginous hard clay, at a depth of a few in. to 2 ft.; it probably extends much deeper, but the natives are too lazy to look for it. It is dug for during and after the last and heaviest rains, in March–May, no trees and but little grass growing above the spots where it is sought for. The resin is collected by the negroes, who at the same time gather dye-plants and gums, with the latter of which, no small quantity of copal is surreptitiously mixed. The copals of the Gaboon and Loango figure chiefly in French commerce; the large masses from Angola, Benguela, and the Congo go principally to N. America, and in minor quantities to Lisbon and other European ports. The total exports are estimated at about 2 million lb. annually.

The copals of N. and S. Guinea exhibit very distinct differences. Those of the former are divided into 2 kinds, known as "young and pebble copals of Sierra Leone." To the latter, belong the copals of Angola, Benguela, and the Congo. These three are so much alike that they are always placed together, and are known simply as "Angola." The copals of Gaboon and Loango are quite distinct again.

The "young copal of Sierra Leone" is said by Daniell to be derived from the living stems of *Guibourtia copallifera.* It consists of globular or tear-like pieces ⅓–1 in. diam., sp. gr. 1·06, of about the same hardness as S. American copal (Jutahy-seca), and of similar commercial value. It is consumed chiefly in England.

The "pebble copal of Sierra Leone" is in small pebbles ⅔–1 in. diam., colourless or white to yellowish, homogeneous, translucent to transparent, with rough exterior, and occasionally covered with an opaque crust of the thickness of paper. It is quite odourless and flavourless, is the hardest of all the W. African copals, and has a sp. gr. of 1·09.

Gaboon copal occurs in round, flattened pieces ⅓–2⅔ in. diam.; the surface is mostly smooth, but is sometimes covered with a crust of branchy striations. The grains are wine-yellow, less transparent and less homogeneous than the foregoing kind; their sp. gr. is 1·073. The fracture is conchoidal to splintery, and of glassy lustre when fresh. The scratch-line on newly fractured surfaces is smooth; on older surfaces, splintery.

Loango copal occurs in broken sticks whose natural length must amount to several spans. According to the colour, two kinds are distinguished, a white and a red. The former consists of colourless or white to yellowish grains; the latter, of reddish or brownish grains or fragments. The red copal of Loango is preferred to the white, on account of superior hardness, transparency, and homogeneity. Its sp. gr. is 1·064. The fracture is conchoidal and glistening, and the scratch-line is free from splinter. The powder does not adhere to the teeth.

Angola copal forms globular, rarely flattened pieces. The former are 1–2⅔ in. diam., while occasionally lumps as large as a child's head, and weighing 3–4 lb., are unearthed. The natural pieces are coated with an earthy, dirty-white to brown crust, which is often facetted like the surface of Zanzibar copal. But the excrescences on Angola copal are much larger than on any E. African copal, their length reaching 0·15–0·45 in. Homogeneous pieces are rare. The grains and sticks are mostly cracked, penetrated by air-bubbles, and contain fragments of bark. This copal is partly colourless, partly yellowish, reddish, or brownish. The colourless or slightly coloured are dull; the strongly coloured are bright, transparent, and homogeneous. The latter have consequently a higher price. On fresh surfaces, the scratch-line is smooth; on older, somewhat splintery. The sp. gr. lies between 1·062 and 1·081.

Hatschett states that some copal is soluble in hot alkaline leys, but Filhol says that E. Indian (which may be Zanzibar or Manilla) is not soluble even after some hours. According to Berzelius, several copals are soluble in spirit of wine on the addition of camphor. Cloëz says that copal (kind not specified) is largely soluble in chloroform, slightly in absolute alcohol. Draper names cajuput-oil as a good solvent. Copal (kind not stated) is insoluble in linseed-oil, but soluble in castor-oil, the solution mixing with spirit of wine, but, separating on standing. Violette states that Calcutta copal is soluble in linseed- and turpentine-oils, when previously heated at 350°–400° (662°–752° F.) in a closed vessel, and that the solution gives a fine varnish. Filhol remarks that the proportion of carbon diminishes in powdered copals by long keeping, and that such then become completely soluble in alcohol, ether, and turpentine-oil. (See also Varnish.)

The hardness of the copals is one of their most characteristic features, and its degree is the principal consideration in estimating their commercial value, increasing in the same proportion. All copals are scratched by calc-spar; but all, with the exception of the S. American (Jutahy-seca) scratch talc. The hardest copals are those whose hardness lies between that of crystallized copper sulphate and rock-salt, softer than the latter, harder than the former; to these, belong Zanzibar and Mozambique copals. The hardness of the copals of Sierra Leone, Gaboon, and Angola resembles that of rock-salt. Softer are those of Benguela, New Zealand (Kauri), and Manilla (Dammar), while softest of all is S. American (Jutahy-seca). The sp. gr. of the copals varies considerably, according to the amount of air inclosed in the cavities. This variation is shown in the annexed table:—

	Sp. gr. before Exhausting.	Sp. gr. after Exhausting.	Difference.
Zanzibar copal	1·067	1·068	0·001
Angola „	1·064	1·081	1·017
Brazilian „ (Jutahy-seca)	1·018	1·082	0·064
Australian „ (Kauri)	1·050	1·115	0·065
Manilla „ (Dammar)	1·062	1·121	0·059

It thus appears that the sp. gr. of a copal is in inverse proportion to its value; and that while the soft inferior copals contain much air, the hard valuable ones have less.

The London market values of the copals are approximately as follows:—Zanzibar (called "animi"): fine washed, 14–23*l.* a cwt.; good, 12–19*l.*; sorts and small, 9–16*l.*; pickings, &c., 4–12*l.* Copal: Angola, red, 3–7*l.* a cwt.; Benguela, 3*l.*–3*l.* 10*s.*; Sierra Leone, 7½–10*d.* a lb.

For the other so-called copals, see as follows:—Dammar, p. 1644; Piney, p. 1678; Jutahy-seca, p. 1666; Kauri, p. 1666.

Dammar, Damar, or Dammer (Fr., *Dammar*; Ger., *Dammar*).—The name "dammar" is applied generically to a number of resins having similar properties, and distinguished by specific prefixes. They will be described here in the following order:—(1) Dammar proper, or E. Indian dammar; (2) Sal dammar; (3) Black dammar; (4) Rock dammar.

1. *E. Indian Dammar.*—This product, which is also known as "Singapore" or "white" dammar, is obtained from the gigantic Amboyna pine (*Dammara orientalis*), a native of Malacca, Borneo, Java, Sumatra, and the Moluccas, growing in the hilly country, and also cultivated to some extent in Java. The main supply of the resin is furnished by Amboyna. Immediately above the root of the tree, occur numerous excrescences, sometimes as large as a man's head, whence exudes an agglutinative liquid that solidifies after some days into elongated masses of resin. In Sumatra, the natural exudation is so abundant that no trouble is taken to make incisions in the trees. In other places, the supply is increased by making incisions on the lower portion of the trunk, and placing small receptacles for the collection of the resin. The dammar which exudes from the upper portion of the trunk forms large stalactites, at first vitreous and colourless, but gradually becoming golden-yellow, which are detached at intervals. In the dense mountain forests of Sumatra, huge pieces of dammar fall from the trees and get washed into the rivers, whence they are collected by the natives.

This kind of dammar usually occurs in commerce in nodules ⅛–¼ in. diam., occasionally of much larger size. The exterior is coated with white powder from mutual attrition, while the mass is straw-coloured or pale-amber, transparent or translucent. It splits readily, and is very friable. It is scratched by copal, and some even by mica, but is harder than rosin. It adheres only feebly by heating in the hand. It softens at about 100° (212° F.), and commences to melt at 150° (302 F.) to a clear liquid of agreeable resinous odour. The fracture is conchoidal and vitreous, and generally exhibits abundant air-bubbles and some vegetable débris. The resin splits and cracks at the temperature of the hand. The odour is balsamic when the resin is new; afterwards imperceptible. The flavour is slightly resinous; sp. gr. 1·062–1·123. It yields a small quantity of lime to water; is incompletely soluble in cold alcohol, moderately soluble in ether, soluble in boiling alcohol, fixed and volatile oils (especially turpentine- and boiling linseed-oils), chloroform, carbon bisulphide, benzol, and petroleum-spirit; but insoluble in acetic acid, nitric acid, caustic soda, and ammonia.

It is extensively used in the manufacture of varnishes for coach-builders and painters, and in mounting microscopic objects, and has long been recommended for making sticking-plaister. Inferior qualities are used in the locality of production for caulking ships and burning as incense; also for illumination, when pounded and filled into tubes of dried bamboo-stems or palm-leaves.

The exports of dammar (quoted as "gum mastic" in the Consular reports) from Manilla in 1879 were 1356 *piculs* (of 139½ lb.) to Great Britain, and 550 to the Straits and India; total, 1906 *piculs*, value, 1525*l.* And the value of the "gum" exported in 1880 was 9600*l.*

2. *Sal Dammar.*—This is produced by the *sal* tree, *Shorea* [*Vatica*] *robusta* (see Timber—Sal), in the tropical Himálaya, and along its base from Assam to the Sutlej, in the E. districts of Central India, in the W. Bengal hills, and in Borneo and Sumatra; also by this species or *S.* [*V.*] *sericea* in Malacca, and possibly by *S.* [*V.*] *Tumbuggaia* [*penicillata*] in the W. Peninsula and the forests of Cuddapa and Palghaut in Mysore. Sal dammar occurs in brittle, stalactitic pieces, pale cream-yellow, nearly opaque, each piece being striated, as if the resin had run out in thin liquid streams, and coagulated on the surface one over another. Its sp. gr. is 1·097–1·123; it is easily fusible, partially soluble in alcohol, almost completely in ether, perfectly in turpentine-oil and fixed oils, and more freely and speedily in benzol than in turpentine-spirit. These solutions are turbid. The turpentine solution (2 parts resin to 2½ parts turpentine-oil) makes a good varnish for lithographic drawings, being clear, nearly colourless, and drying rapidly without cracking; also a moderately good tracing-paper. The resin occasionally appears in the English and French markets.

3. *Black Dammar.*—The black or *kala* dammar of India is derived from one or more species of *Canarium*, the chief being *C. strictum.* This tree is common in the Alpine forests about Courtalum, in the Tinnevelly district, and is there regularly rented for the sake of its dammar. In this locality, the resin is obtained by making a great number of vertical incisions in the bark near the base of the trunk, then setting fire to the tree below the cuts, and having thus killed it, leaving it for a couple of years before collecting the exudation. The tree is killed in the hot season, and the gathering takes place in February–March. In the Coimbatore district, the dammar is extracted

from the tree by piling firewood to the height of 1 yd. around the base of the trunk, and lighting it. The resin subsequently exudes from the trunk as high as the flames reached. The operation is conducted at any season of the year, and the dammar continues to flow for 10 years between the months of April and November, and is collected in January. After yielding for 10–12 years, the tree decays. The quantity of resin obtained is stated at 30–40 *dungallies* (say 150–200 lb.). It occurs in large stalactitic pieces, of bright black colour, when viewed from a distance, but translucent and deep reddish-brown when seen in thin laminæ against the light. It is quite homogeneous, and has a vitreous fracture. It is insoluble in cold, but partially soluble in boiling alcohol on the addition of camphor. When powdered, it is readily soluble in turpentine-oil. By distillation, it yields about 78 per cent. of oil resembling rosin-oil. It is largely used in India in making bottling-wax, varnishes, &c., but in this country would hardly compete with common rosin.

Another species, *C. bengalense*, of Sylhet and the adjacent mountainous countries, yields a large quantity of pure, clear, amber-coloured resin, which soon becomes hard and brittle, and is not unlike copal, but lightly valued by the natives.

4. *Rock Dammar.*—This is furnished by two species of *Hopea*, *H. odorata* of Rangoon, Pegu, Martaban, and Tenasserim, and *H. micrantha* of Malacca, Sumatra, Borneo, and Labuan. The resin of the former occurs in nodules about the size of walnuts, of a pale-straw colour to colourless, brittle, with a shining resinoid fracture, scarcely distinguishable in appearance from the commercial E. Indian dammar (of *Dammara orientalis*). It dissolves readily in turpentine-spirit and benzol, forming a clear bright solution, drying rapidly and smoothly when applied as a varnish. In all essential qualities, it is quite equal to E. Indian dammar, and is rather superior to it in hardness. The resin of *H. micrantha* is met with in pieces having the same size as the foregoing, but darker coloured and less friable. In other respects, there is no broad difference between the two kinds.

The 1877 crop of dammar exported from Java was distributed as follows:—8272 *piculs* (of 135½ lb.) to Holland, 3674 to Singapore, 1050 to France, 736 to the Channel for orders, 615 to America, 14 to Italy; total, 14,361 *piculs*. The 1878 crop:—4161 to Holland, 2375 to France, 1721 to America, 1345 to Singapore, 410 to England, 213 to the Channel for orders; total, 10,225 *piculs*. The 1879 crop:—6820 *piculs* to France, 4413 to England, 2968 to Holland, 1957 to Singapore, 1887 to America, 814 to the Channel for orders, 343 to Italy, 262 to Port Said for orders; total, 19,464 *piculs*. The state of Sarawak, in 1879, exported 407 dollars' worth (of 4*s.* 2*d.*) to foreign countries. The approximate London market values of the dammars are as follows:—Manilla (called "copal"), 16–65*s.* a cwt.; Batavian, 70–115*s.*; Singapore, 55–105*s.*

It must be acknowledged that our information concerning the dammars of the E. Archipelago and their sources is far from being comprehensive. There are many similar products of that region of which we know practically nothing.

Dextrine, British Gum, Starch-gum, Fruit-gum (Fr., *Amidon-grillé*, *Gomme d'Alsace*, *Leiogomme*, *Gommline*; Ger., *Dextrin*, *Leiocom*, *Stärkegummi*, *Stärkemehlgummi*).—This substance, whose formula, $C_{12}H_{10}O_{10}$, is homologous with that of starch, occurs sparsely in many plants, and seems to play an important part in the development of those parts of plants in which a new formation of cells takes place. Its presence in various grains (air-dried) amounts to the following percentages:—Wheat, 4·5; wheat-bran, 5·52; barley, 6·55; rye-bran, 7·79; malt, 8·23. It is more abundant as a transformation-product of grain-starch in bread, beer, and other substances manufactured from grain; and is found also in the blood, muscle, spleen, and liver of animals, particularly graminivorous.

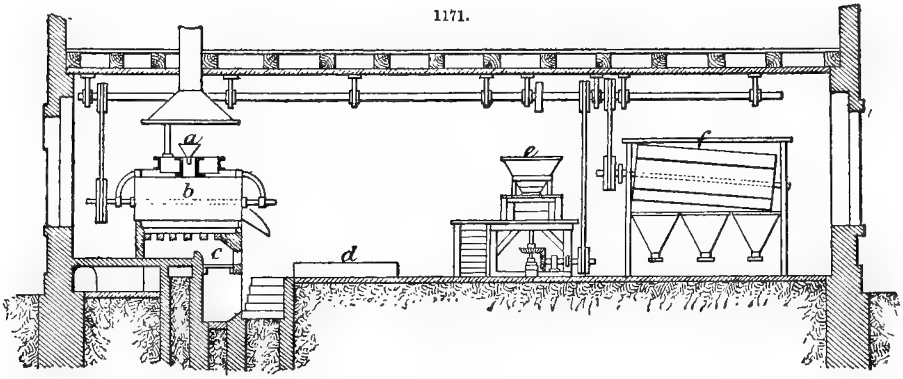
Pure dextrine is a white, amorphous, flavourless and odourless powder, sp. gr. 1·52. It is completely soluble in cold water, forming a glutinous mucilage. Commercial dextrine usually leaves a residue of 12 per cent. or more of unchanged or burnt starch. It is insoluble in absolute alcohol and in ether. Heated with dilute acids (sulphuric, hydrochloric, or acetic), it is partially transformed into grape-sugar. Alone, it is unfermentable. Heated in the presence of an inert vapour laden with moisture, it is converted into sugar, the amount of glucose thus formed increasing as the starch used is more acetous.

Commercially, the term "dextrine" is restricted to starch-dextrine prepared by the artificial transformation of starch. This may be effected in 3 ways:—(1) By the prolonged roasting of dry starch at a temperature of 200°–275° (392°–527° F.); (2) by heating starch with dilute acids for a short period; (3) by treating starch with a solution of diastase (malt-extract) at a temperature of 60°–75° (140°–167° F.). In all these cases, the formation of a certain quantity of glucose is a necessary accompaniment of the operation. In the industrial manufacture of dextrine, the dual object aimed at is the most complete transformation of the starch into dextrine, with the least possible co-production of glucose. Absolute purity is a matter of minor consideration, the technical application of the material demanding chiefly an article that will paste and thicken well. The starch employed may be of any origin, and such as is most cheaply and readily procurable on the spot (see Starch).

In manufacturing dextrine by the roasting process, it is essential that the transformation shall go on evenly and at one temperature. The limits of temperature commonly adopted are 212° and 250° (413½°–482° F.), though Payen says that a temperature of 200°–210° (392°–410° F.) produces the most perfectly soluble dextrine. Several methods are adopted for conducting the manufacture at an equable temperature, one of the best being based on the principle of an oil-bath.

This form, adopted by Proudfoot & Co., Manchester, who produce nearly 4 tons daily of dextrine, is shown in Fig. 1171. It is suited to the treatment of wheat-, rice-, and potato-starch, but only produces the article in powder form, not in transparent pieces. The starch is first dried at 80° (176° F.) in an apartment for the purpose; its subsequent loss of weight in roasting is small, 220 lb. of starch giving 176 lb. of finished dextrine of good quality. The starch is fed in through the oval hopper *a*. The double-jacketed cylinder *b* is supplied with well-refined rape-oil up to a gauge-cock. A fire is then kindled in the furnace *c*, the stirrer in the inner receptacle of the cylinder *b* is put in motion, and the starch, in charges of about 5 cwt., is introduced from the hopper *a*. The oil rapidly expands by the heat, so as to completely surround the inner cylinder of *b*. The temperature to which the oil is heated varies with the grade of dextrine required. The roasting is known to be complete when a peculiar decided odour is emitted at the hopper. The material is then withdrawn into the metallic dish *d*, about 8¼ ft. long and 4 ft. wide; the larger pieces are crushed and sifted before being pulverized in the mill *e*. It is finally placed in a sieve-drum or gauge-cylinder *f*, and is then ready for packing.

1171.



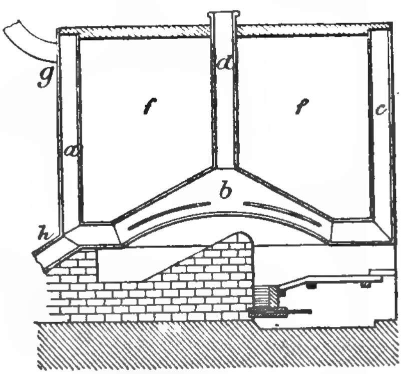
The oil can be used repeatedly, requiring only occasional replenishing as it becomes oxidized. The roasting-cylinders are best made of wrought-iron, and about 10 ft. long and 1 ft. in diameter. They are placed on a slight incline, and may be so adjusted as to work continuously, the finished product escaping at one end while the dry starch enters at the other. Several such cylinders may be placed over the same furnace, and rotated by cog-wheels. The darkest qualities of dextrine require a second roasting at a high temperature.

Payen's hot-blast furnace consists of an upper portion filled with brass trays, in which the dry starch is spread in a layer of 1–1½ in.; air, entering and circulating through passages, is heated by a furnace, and escapes into the upper chamber containing the starch; parting with its heat to the latter, it descends again to be reheated. During the first part of the operation, an exit is provided for the moisture-laden air. The great faults of this system are the impossibility of regulating the temperature, and the inequality in the roasting by reason of the starch remaining stationary.

The manufacture of dextrine by the acid process depends on the fact that anhydrous starch, moistened with a dilute scarcely-volatile acid, and heated to 100°–125° (212°–257° F.), is transformed into dextrine. Great care is necessary in arresting the process as soon as the dextrine is formed, to prevent its further conversion into sugar. The starch is mixed with a quantity (determined by experience) of dilute acid so as to form a damp powder; this is exposed to a temperature of 100°–120° (212°–248° F.) until the transformation is complete. The acids chiefly used are nitric and hydrochloric; it is essential that they contain no free chlorine, or it would pass over into the dextrine, and bleach the colours employed with the latter in printing paper, calico, &c. Sulphuric acid is seldom availed of, except for making liquid dextrine; dextrine made with it never becomes really dry, and is generally of darker colour. For the production of liquid dextrine, both oxalic and lactic acids are likewise employed, their excess after completion of the transformation being neutralized by carbonate of lime.

By Anthon's method, the pure starch is replaced by potatoes themselves, previously freed of soluble ingredients by treatment with acidulated or alkaline water, then dried, and ground fine. This material is acidulated with nitro-hydrochloric acid at the rate of 0·05–0·1 per cent. on the weight of starch. The acidulated mass is spread on linen hurdles in a drying-room at 38°–44° (100⅓°–111¼° F.) till it ceases to lose weight, when the temperature is raised to 70°–75° (158°–167° F.) for a time, and is finally increased to 90° (194° F.), and thus maintained for ½ hour, when the perfectly dry substance, while still hot, is placed in tin-plate moulds at 100°–125° (212°–257° F.) for 1–2 hours, by which the formation of the dextrine is completed. The final heating in the moulds is conducted in the apparatus shown in Fig. 1172. This consists of a double-jacketed kettle, whose outer receptacle *a b c* serves as a salt-water- or oil-bath, being supplied through *d*. The outer shell is encased in felt and wood; the false bottom *e* helps to facilitate the circulation of the contents of the bath. The inner receptacle is divided into a series of flat cells *f* about 1 in. diam., containing the starch to be converted. The pipe *g* serves to admit cold air or liquid into the jacket, of which the pipe *h* is the outlet.

1172.



An approved recipe for making dextrine by oxalic acid is :—500 lb. potato-starch (or an equivalent of grain-starch), 1500 lb. water, and 8 lb. oxalic acid, heated in a water-bath till the liquor ceases to give a blue colour with tincture of iodine, cooled off, neutralized with chalk, left for several days, filtered, evaporated to a doughy consistence, and slowly and completely dried.

The manufacture of dextrine by means of fermentative bodies, such as diastase, is now conducted only on a very small scale; the product always contains an appreciable quantity of sugar, and is qualified by the term *sucrée* among the French firms who make it. The process consists in heating a mixture of starch, diastase, and water at 65°–75° (149°–167° F.), and boiling the mass immediately the conversion is finished, so as to arrest as far as possible the further transformation into sugar. The syrupy nature of the article makes it difficult of transport, and it is very liable to ferment.

Mention may here be made of Pochin and Wooley's method. Thoroughly dried starch is mixed with 12½–25 per cent. of butter-milk or sour milk passed through a sieve of 40 meshes per sq. in., redried, and gently roasted till the colour is yellow to brown.

Experiments to produce dextrine from cellulose have been total failures.

Commercial dextrine is never quite pure, and rarely required to be so, but it may be rendered so by first decolorizing its aqueous solution by means of bone-black, filtering off, evaporating down, and treating with alcohol to separate the sugar; the flocculent precipitate of dextrine is filtered off, dissolved in water, and treated with alcohol, this rotation being repeated 10–12 times. The purification of dextrine made by diastase is a much more complicated matter.

Commercial dextrine varies widely in quality. It occurs most commonly as a dirty-white or pale-yellow powder, and formerly was made exclusively in this form; but latterly, it has been extensively manufactured in lumps bearing a close resemblance to Arabic and Senegal gums. Finally there is dextrine-syrup, a pale-yellow, transparent, tough, glutinous mass, used by brewers in France, but little known elsewhere. An idea of the percentage composition of dextrine intended for industrial application may be gained from the following analyses :—

	Dextrine.	Sugar.	Insoluble.	Water.
Prime dextrine ..	72·45	8·77	13·14	5·64
Dark-roasted ..	70·43	1·92	19·97	7·68
Brown dextrine ..	63·60	7·67	14·51	14·23
Gommeline ..	59·71	5·76	20·64	13·89
Older dextrine ..	49·78	1·42	30·80	18·00

Its composition is so various, and it is so often adulterated, that it should always be bought on analysis, and carefully tested.

It is very largely used in printing calicoes, glazing paper, gumming envelopes and stamps, making inks and printing-rollers, coating sticking-plaister and bandages, baking bread, and brewing beer. It is said never to become mildewed. Its approximate value is 30*s*. a cwt. in 6-cwt. casks.

Dhoura, Thoura, or Dhowra.—This gum exudes from incisions made in the bark of *Anogeissus* [*Conocarpus*] *latifolia*. The tree inhabits Islamabad, the Kennery jungles, the valleys of Concan rivers, and the inland Dekkan hills; it is very plentiful in the Melghât. A good specimen of the tree yields about 4 lb. of the gum. It is gathered carelessly, before it is sufficiently dry to come away by itself, and is much contaminated with bark, leaves, and sand. Picked samples consist of cylindrical or vermiform tears, ½ in. diam., 1½ in. long, clear, transparent, almost colourless, forming a clear, colourless mucilage with cold water, but with a small proportion of insoluble bassorine swelling up. When the latter is strained off, the mucilage is quite clear, and as tenacious as arabic. Four reports on an unpicked ordinary sample of the gum placed the probable market value at sums varying from 10 to 25*s.* a cwt. It was classed as a very low arabic; but if picked clean, and offered in quantity, it would probably soon command a better price than the maximum estimate.

Dika-mali or Cumbi, and Ouliépé.—Two species of *Gardenia*, *G. lucida* and *G. gummifera* [*arborea*], which are common in many parts of India, yield a resinous exudation; it occurs in irregular earthy-looking masses of dull olive-green colour, consisting of a mixture of the resin and its natural impurities. Its odour is peculiar and very offensive. A spirituous solution is used in dressing ulcers and to prevent mortification. Both the resin and the twigs coated with it are sold in the Indian bazars.

In New Caledonia, a yellow, aromatic resin, of disagreeable flavour and glossy fracture, is obtained from the buds of *G. Ouliépé*, *G. edulis*, and *G. sulcata.* It occurs as a powder, and in compact lumps. It closely resembles the Indian *dika-mali* or *cumbi*, and is employed by the natives as a cement and for caulking ships.

Dragon's-blood (Fr., *Sang dragon*; Ger., *Drachenblut*).—This name is applied to resins obtained from several different species of plants. The most important of the resins, and the one usually known by the name of dragon's-blood, is afforded by *Calamus Draco*, of E. Asia. Other kinds of minor significance, which will be described after the chief sort, are (2) Socotran, (3) Canary Islands', (4) W. Indian, and (5) Mexican.

1. *E. Asian.*—The distribution of *Calamus Draco*, whose stems constitute the bulk of the rattan canes of commerce, has been recorded under Cane, pp. 595–8. The abundant fruit, on arriving at maturity, is covered with an exudation of red resin, of naturally friable character. This is dislodged by gathering the fruits, and shaking or beating them in a sack or basket, when the freed resin can be sifted clean from impurities. Exposed then to the heat of the sun, or of boiling water in a closed vessel, it is softened so that it can be moulded into sticks or balls, which are immediately wrapped in a palm-leaf, generally from *Licuala spp.* This forms the best kind, or *jernang*, the "dragon's-blood in reeds" or "sticks," of commerce. The sticks have sometimes a length of 13–14 in., and a diameter of ¾–1 in., weighing about 5 oz.; smaller ones are more common. The surface of the resin appears of an intense blackish-brown; in thin pieces, it is transparent, and of a pure brilliant crimson. It has a sweetish flavour, and gives a blood-red streak on paper. The sp. gr. is about 1·2, being somewhat higher in the good qualities, and lower in the inferior. These inferior qualities are produced by boiling the pounded fruits in water, and making the resin into a mass, frequently increased by the fraudulent addition of dammar and other foreign matters. The article is known as "lump." It has a slightly acrid flavour, a weaker colour, and a much larger percentage (40 or more) of insoluble matters. Dragon's-blood melts at about 120° (248° F.), with evolution of benzoic acid. It is soluble in the alcohols, benzol, chloroform, carbon bisulphide, the oxygenated essential oils, petroleum-ether, glacial acetic acid, and caustic soda; sparingly so in ether, and still less in turpentine-oil. It is largely sent into Chinese, Indian, and European commerce from Singapore, Batavia, and Banjarmassing. It is used as a colouring agent in pharmacy, but much more extensively for making varnishes, particularly those employed by furniture-polishers.

2. *Socotran.*—The dragon's-blood of Socotra, well known in ancient medicine, is obtained from *Dracæna Ombet*, or possibly *D. schizantha*, a mushroom-like tree of 20 ft., growing only at an elevation of about 1500 ft. To obtain the resin, called *eda* by the natives, about 4 sq. in. of bark is removed, and the cavity thus formed becomes filled with the exudation in 2–3 weeks. The collection takes place in March. The product is sent from Muscat and Aden to Bombay, where it is used by the goldsmiths.

A closely similar, if not identical, article is produced by *D. schizantha*, a 25-ft. tree growing in the Somali country at 2500–5500 ft., and there called *moli.* It is said not to be exported, but either this or the foregoing kind occasionally appears in the London market in small parcels from Bombay and Zanzibar, bearing the name of "drop" dragon's-blood. It is in little tears and fragments, of clean glassy fracture, and transparent and ruby-coloured in thin sections. It is free from fruit-scales, and evolves no benzoic acid on heating.

3. *Canary Islands'.*—The dragon's-blood of the Canary Islands is obtained from *Dracæna Draco*, by making incisions in the stem. This resin is found in the sepulchral caves of the Guanches, and is supposed to have been used by them for embalming. It formed at one time a considerable article of export from the Canaries, and has not quite fallen into disuse, though it is never met with in ordinary commerce.

4. *Mexican.*—*Croton Draco*, of Mexico, yields a resin used in varnish-making, which occasionally passes by the name of dragon's-blood.

The approximate London market value of dragon's-blood is 4–5*l.* a cwt. for lump, and 10–12*l.* for fine reed.

Elemi (Fr., *Elémi*; Ger., *Elemi*).—The term "elemi" is applied to a number of resinous exudations (some confounded with animi), the chief of which is obtained from the Philippine Islands. The description of this will be followed by some account of (2) Mexican, (3) Brazilian, (4) Mauritius, (5) E. African, (6) W. African, and (7) W. Indian elemis.

1. *Philippine.*—The oleo-resin known as Manilla or E. Indian elemi has long been attributed to *Canarium commune*; this has recently been doubted by competent authorities, who are rather inclined to consider the plant a *Bursera.* It forms a tree, growing in the province of Batangas, in the island of Luzon, where it is called *abilo* by the natives, and *arbol a brea* ("pitch-tree") by the Spaniards, from the use of the resin for making torches. The resin as imported is soft, of granular consistence resembling old honey, and colourless when fresh and pure, but more usually contaminated with chips and carbonaceous matter, rendering it grey or blackish. It hardens and becomes yellow on exposure. It has a strong odour of fennel, lemon, and turpentine. It softens at 80° (176° F.), and fuses to a clear resin at 120° (248° F.). It is adopted by the British Pharmacopœia, and is imported in large quantities from Manilla. It is used principally in the manufacture of varnishes; also in felting and in medicine.

2. *Mexican.*—Mexican or Vera Cruz elemi is produced by *Amyris elemifera* [*Plumieri*], growing in Mexico and Yucatan. It is a light-yellow to whitish brittle resin, in semi-cylindrical or irregular fragments, translucent to dull and opaque. It has an agreeable odour of turpentine, and is readily masticated. It was met with in London commerce 30 years since, but is unknown now.

3. *Brazilian.*—This heading embraces the products of several species of *Icica*, as *I.* [*Protium*] *Icicariba*, *I. heterophylla*, *I. heptaphylla*, *I. guianensis*, *I. altissima*, *I. Caranna*, *I. viridiflora*, growing in Brazil, Guiana, and New Granada (Colombia). The so-called "balsams" obtained spontaneously from their trunks are highly odoriferous, and commonly used as incense in S. America. This is particularly the case with that of *I. heptaphylla*, called *hyawa* gum or *conima* resin in Guiana, and whose timber is known as "incense-wood"; and with that of *I. heterophylla*, termed "balsam of Acouchi." *I. Caranna* is named as the source of "caranna" resin, used medicinally by the Indians of Central America; but Hanbury attributes at least one kind of so-called *caranna*, *carayne*, or *caraña* gum or resin to *Bursera acuminata.* These exudations remain fluid for a considerable time, but ultimately harden. They are strangers to European commerce.

4. *Mauritius.*—Mauritius elemi is produced by *Colophonia mauritiana*, and bears a close general resemblance to the Philippine article, with which it is perhaps identical.

5. *E. African.*—See Olibanum, p. 1676.

6. *W. African.*—It is said that large cakes of elemi used to be brought to Bembe, and that it is abundant at not many days' journey; but there is possibly some confusion here with animi or copal. Nevertheless Holmes, in 1879, described an elemi from an *Icica sp.* received from Liberia under the name of copal. Externally, it seemed inferior, having a dirty blackish appearance, the white opaque porous resin only showing here and there; the odour resembled the true drug, but the article was much drier and more friable. Analysis proved it to be comparatively pure, thus—resin soluble in cold alcohol, 84·5; resin soluble in ether, 12·0; black insoluble residue, 3·5. This last is of vegetable origin, and almost exclusively fungoid or algal filaments.

7. *W. Indian.*—Wiesner describes an exudation from *Bursera gummifera* in Martinique and Guadeloupe, forming large white masses, internally greenish to yellowish.

Euphorbium (Fr., *Euphorbe*; Ger., *Euphorbium*).—This gum-resin is obtained from *Euphorbia resinifera*, a tree confined to the interior of Morocco, growing on the lower slopes of the Atlas in the S. province of Suse, and in Demenet, and notably at Netifa and Imsfuia (Mesfioua). Incisions are made by a knife in the green fleshy branches, whence exudes an abundance of milky juice, which hardens on exposure, encrusting the stems down which it flows, and is collected in September. The collectors adopt the precaution of covering mouth and nose during the operation, to exclude the small dusty particles, which provoke intense sneezing. The gum-resin once had a wide medicinal use, but the trade in it is now rapidly declining, and its consumption is restricted to veterinary practice, and as an ingredient of a marine paint. What little is exported is shipped at Mogador. Our imports in 1870 were 12 cwt.; since then there is no return. A small quantity recently sold in London at 28*s.* a cwt.

Frankincense.—The name frankincense properly belongs to olibanum, and the true drug will be described under that head (see p. 1676). The term "common frankincense" is a synonym for gum thus, a coniferous product (see Thus, p. 1684). and is also applied to another pine-resin). There remains the resinous exudation known as "W. African frankincense" for description in the present article.

The tree affording this, *Daniellia thurifera*, is a native of Sierra Leone and circumjacent regions, being especially abundant in the mountainous districts W. of Freetown, and the wooded slopes near York, Lumley, and Goderich villages. It is said also to be met with on the forest declivities of

Fernando Po, and in Yoruba, where it is called *ogea*. In Sierra Leone, both the tree and the exudation are termed *bungo*. The naturally exuded gum-resin mostly appears in a liquid state, of white or pale-straw colour; in some seasons, it oozes so copiously from the branches that the ground and shrubs beneath become thickly covered with white spots. This does not occur so profusely from the cortex, and, when so produced, appears in thin, shallow, whitish streaks, resembling a saline efflorescence when dry. The natural exudation would not appear to be gathered. But the tree is much attacked by an insect which perforates the bark in all directions, and through the apertures made by it, the gum-resin issues as a liquid mingled with and coloured by the woody débris, and accumulates in masses, which fall to the earth, harden, and are collected for sale. Further quantities are procured by stripping dead or unsound bark from the tree, the more decayed portions being commonly saturated by the exudation. Both kinds, frequently mixed, appear in the market at Freetown, and are largely consumed locally by the native women for anointing. The product seems to be unknown in European commerce.

Galbanum (Fr., *Galbanum*; Ger., *Galbanum, Mutterharz*).—Premising that much ignorance still surrounds the origin of this medicinal gum-resin, it seems to be at any rate chiefly derived from two species of *Ferula*. These are: (1) *F. galbaniflua*, the *khassuch* of the Persians, and *boridsheh* of the Mazanderan dialect, inhabiting the foot and slopes (4000–8000 ft.) of the Demavend mountains in N. Persia, the mountains near Kushkak and Churchura (Jajarud), and the neighbourhood of Sabsawar; and (2) *F. rubricaulis* [*erubescens*], growing in the gorges of the Kuh Dinar range in S. Persia, and locally throughout the whole of N. Persia, as on the Dalmkuh mountain, on the slopes of the Elvend near Hamadan, at intervals on the edge of the great central salt-desert of Persia, on the mountains near Sabsawar, between Ghurian and Khaf, west of Herat, and on the desert plateau west of Khaf. The gum-resin of the former species is said to be gathered by the inhabitants of the district of Demavend, though it is not any special object of industry; that of the latter species is collected for commercial purposes around Hamadan, and constitutes "Persian" galbanum.

Existing accounts of the collection of galbanum are imperfect and contradictory; possibly different systems prevail in different localities. Buhse states that the gum-resin exudes freely and spontaneously from the lower part of the stem and the bases of the leaves. Geoffroy says that it is extracted by making large incisions in the stem at about 3 in. above the root, when it escapes in drops, and at the end of a few hours has dried sufficiently to be collected. Landerer asserts that the stem is scarified, and a mussel-shell placed beneath to catch the exudation. The appearance of the bulk of the galbanum of commerce favours the supposition that it is principally drawn from incisions in the roots, few samples occurring free from an abundance of root-fragments.

Galbanum is usually classified into two kinds, "tears" and "lump." The drops or tears of Levantine commonly adhere so as to form a mass, generally compact and hard, but the Persian are occasionally soft to fluidity. Their size varies from that of a lentil to that of a hazel-nut; and their colour, from light-brown to yellowish or greenish. The odour is peculiar, aromatic, and not unpleasant; the flavour, bitter, alliaceous, and objectionable. In some samples, the tears are dull and waxy, changing from light-yellowish to orange-brown by keeping, with little disposition to concrete, and a savin-like odour. The sp. gr. of the drug is about 1·212. It consists essentially of about 50–70 per cent. of soft resin, soluble in ether and alkaline leys (even milk of lime), but not entirely in carbon bisulphide; 3–7 per cent. of volatile oil; and 18–23 per cent. of a gum resembling bassorine in its solubility.

The so-called "Levant" galbanum enters Europe viâ Trieste and Marseilles. Some is said to reach London from Bombay. Very large quantities pass into Russia by way of Astrakan, Orenburg, and Nijni-Novgorod, wrapped first in skins and then in mats, and each package weighing about 60–80 lb.

The uses of galbanum are almost wholly medicinal (see Drugs, p. 811), though it is said to be an ingredient of some cements.

The approximate London market value of galbanum is 6*d.*–1*s.* 3*d.* a lb.

Gamboge (Fr., *Gomme Gutte*; Ger., *Gutti, Gummigutt*).—Some account of this gum-resin has already been given under Pigments (see p. 1551). In addition to the species there indicated as affording the pigment, it would seem that a similar colouring matter is derived from *Stalagmites ovalifolius* in Ceylon, and from *Vismia guianensis*, *V. cayennensis*, *V. dealbata* (*lacrezeira* gum in Brazil), and *V. sessiliflora* in S. America, though none of these products is known in European commerce.

The value of the gum-resin for both tinctorial and medicinal purposes is directly dependent upon the proportion of the resin present. Analyses of commercial samples of "lump," "pipe," and "powder" gamboge, by Costelo, show:—

Lump	67·6 resin,	27·4 gum,	3·8 impurities.
Pipe	79·3 „	19·45 „	0·15 „
Powder	76·6 „	22·5 „	0·7 „

The resin ("gambogic acid," $C_{20}H_{23}O_4$) is of bright reddish-brown colour, translucent, very brittle, and easily rubbed into a bright-yellow powder; it is soluble in alcohol, ether, chloroform, carbon bisulphide, ammonia and potash leys, and partially in petroleum-benzine.

Ging and Kunnee.—These names are applied locally to two grades of gum produced by *Odina Wodier*, in the Coromandel mountains and Travancore. The exudation is abundant and spontaneous, and takes place from the bark of the tree, about April. The 1st quality is white, and is called *kunnee*; of it, a man can gather about 2 lb. a day. The 2nd quality is black, and consists nominally of what has fallen to the ground, but is almost invariably mixed and sold with that obtained from *Conocarpus sp.*; of this, one man can collect 10 lb. daily. A good specimen of the tree yields about 5 lb. of gum. It is used by dyers, cloth-printers, in ink, and as medicine. Samples sent into the London market for valuation were reported inferior to chironji (see p. 1639), and priced at 10–30*s.* a cwt., much fault being found with the large proportion of insoluble matters. It was stated that if imported here, it would probably be used only as an adulterant.

Specimens of gum-resin and pitchy resin attributed to the same source must be regarded with doubt. It is to be regretted that more attention has not been paid to the exudations of *Odina Wodier*. Dr. Dymock calls the gum by the names *shimptee* and *mooi*.

Guaiacum (Fr., *Gaïac*; Ger., *Guajacharz*).—This well-known medicinal resin is obtained chiefly from *Guaiacum officinale*, and in minor quantity from *G. sanctum*. Both are natives of the W. Indies, notably San Domingo and Les Gonaives (see Timber—Lignum-vitæ). A small quantity of the resin is collected as a natural exudation in tears from the stems of the trees, but a much larger proportion is extracted artificially. This is performed in several ways. The simplest consists in making incisions in the bark of the living tree. Another method is to support logs of the wood in a horizontal position, to make an incision at the centre, and then to ignite both ends of the log; as it burns, the resin escapes from the incision. A third plan is to expose logs, which have been perforated endwise, to the influence of a brisk fire. A fourth system is to boil fragments of the wood in water, whose density has been increased by the addition of salt; the resin melts out and forms a layer on the surface of the water. The resin occurs commercially sometimes in globular tears ½–1 in. diam., but generally in masses, more or less associated with débris of the wood and bark. It is brittle, with a clean glassy fracture, transparent and greenish-brown in thin pieces. The powder is grey while fresh, but soon becomes green by exposure. The odour is balsamic; the flavour is slight, but leaves an irritating sensation in the throat. The sp. gr. is about 1·12. The fusing-point is 85° (185° F.), when a benzoin-like odour is emitted. The resin is soluble in alcohol, ether, acetone, amylic alcohol, chloroform, creasote, caustic alkaline leys, and clove-oil; slightly in other volatile oils, benzol, and carbon bisulphide. The commercial article is often much contaminated by impurities through carelessness in the collection. It is also adulterated with common pine-rosin, and is itself mixed fraudulently with scammony and jalap. Its uses are wholly medicinal (see Drugs, p. 811). It is imported almost exclusively from San Domingo, whence the exports were 36,350 lb. in 1875, but only 3320 lb. in 1879, and 1830 lb. in 1880; in the two last years, the export was entirely to the United States.

The approximate London market value of guaiacum is 9*d.*–3*s.* 6*d.* a lb.

A so-called "guaiacum" from Peru, recently imported for perfumery purposes, would seem to be a distinct product.

Gurjun-balsam or Wood-oil.—This oleo-resin, whose second name must not be confounded with the fatty oil bearing the same appellation, described on pp. 1411–2, is obtained from several species of *Dipterocarpus*. The most important are *D. turbinatus* [*lævis*, *indicus*] of E. Bengal, Chittagong, Pegu, Singapore, and French Cochin China, and *D. trinervis* of Java and the Philippines. Other species of minor significance are:—*D. incanus* of Chittagong and Pegu; *D. alatus* of Chittagong, Burma, Tenasserim, the Andamans, Siam, and Cochin China; *D. crispalatus* of French Cochin China; *D. zeylanicus* and *D. hispidus* of Ceylon; and *D. gracilis*, *D. littoralis*, and *D. retusus* [*Spanoghei*] of Java.

The extraction of the oleo-resin seems to be everywhere performed in the same manner. The operation mainly consists in scooping a basin-like hole out of the trunk of the tree at a convenient height above the ground, and periodically igniting a fire within the cavity. The heat causes the balsam to flow from the ducts containing it and to collect in the basin, whence it may be dipped or siphoned into receptacles. The tapping is effected at about the end of the dry season, or during November–February. Every 3–4 weeks, the charred surface of the cavity is chipped away, and a fresh fire is made. In large healthy trees, sometimes a second cavity is cut. Trees which appear sickly in the following season are allowed a year or two's rest. Good trees give an average yield of 30–40 gal. during the season. The oleo-resin as extracted is allowed to settle, in order that the clear liquid portion may free itself from the thick sediment or *guad*.

The balsam, being derived from several different trees and various countries, does not exhibit a constancy of character. It may be generally described as a viscid fluid consisting of about 34 per cent. of resin, and 65 of essential oil, highly fluorescent, transparent, and dark reddish-brown against the light, resembling copaiba in odour, flavour, and medicinal properties, but giving no unpleasant smell to the breath. Its sp. gr. is 0·964 at 17° (62½° F.) It is quite soluble in pure benzol, cumol, chloroform, carbon bisulphide, and essential oils; partially in methylic, ethylic, and amylic alcohols, ether, acetic ether, glacial acetic acid, acetone, carbolic acid, absolute alcohol, solution of caustic potash, many samples of commercial benzine, and petroleum-ether. Tests which distinguish it from copaiba have been given on p. 1640.

Gurjun is produced in Canara (S. India) in small quantity. It is exported from Singapore, Moulmein, Akyab, and the Malay Peninsula, and is a common article of commerce in Siam. It occurs abundantly in Samar and Albay, and probably other provinces of the Philippines, where it is known as *balao* or *malapajo*; it is sold in Albay at the rate of 4 *reals* per *tinaja* of 10 *gantas* (say 4½*d.* a pint). It is now regularly to be met with at the London drug sales. Medicinally, it is employed in skin-diseases in England, and as a substitute for copaiba in India. In the Philippines, and other localities of production, it has more importance as a varnish (best after boiling to remove the essential oil), an ingredient of lithographic inks, a preservative for iron (against rust) and for timber (against termites and other insects), and generally for application to the seams and bottoms of boats and ships. As a varnish, it is reported to dry slowly and possess little body, but the case might be different if the essential oil were boiled off.

See also Copaiba, p. 1639; Hardwickia, p. 1654.

Guttapercha.—This name, as naturalized in European commerce, embraces the inspissated juices of several species of sapotaceous trees growing wild in peninsular and insular Malaysia. Their range has been defined as lying between 6° N. and S. of the equator, and between 100° and 120° E. long.; this has been more recently curtailed to 4° N. and 3° S. lat., the finer varieties being confined between 3° 50′ N. and 1° S. lat., where the air is very humid, and the temperature ranges about 19°–32° (66°–90° F.).

The Malay word *gutta* (variously spelt) signifies "gum" simply, while *percha* is the name of the tree. The *guttas* distinguished by the Malays are as follows:—(1) *Gutta-susu*, obtained from a scientifically-unknown tree, now extinct except in the interior of Perak; the product is the most esteemed of any, on account of the firmness of texture. Must not be confounded with the Bornean article of the same name, which is a kind of indiarubber. (2) *Gutta-taban*, the "guttapercha" of commerce, which will receive further attention presently. (3) *Gutta-rambong*, and (4) *Gutta-singgarip*, kinds of indiarubber, and described in that section. (5) *Gutta-puti* or *gutta-sundek*, the product of an undetermined species of *Dichopsis* [*Isonandra*], frequently met with on the Sayong and Meeru ranges (Perak). It is obtained and prepared in the same manner as *taban*, but is much whiter and more spongy, and valued at little more than ¼ the price of *taban*; of it, some 484½ *piculs* (of 133⅓ lb.) were exported from one port in 1877. (6) *Gutta-julatong*, of unknown origin, often used in Perak for mixing with *taban* and *puti*, thus rendering them very brittle. (7) *Gutta-kolian*, said to be derived from *Isonandra* [*Dichopsis*] *Motleyana*, of the Peninsula, Java, and Sumatra; the product is used only for adulterating. (8) *Gutta-burong*, the milks of various species of *Ficus*, employed as bird-lime, and described under indiarubber.

[Since the preceding remarks have been in type, Beauvisage has published a monograph on guttapercha, see Bibliography (p. 1695), which deserves the attention of all interested in the subject; it is too late to do more here than give a brief epitome of his nomenclature:—*Dichopsis* [*Isonandra*] *Gutta* is called *gutta-balam* at Pajakomlao (W. Sumatra) and the Lampongs (S. Sumatra), *gutta-tambaga* at Lobo Along (W. Sumatra), *gutta-dadu* or *-seroja* in Banka Island, *gutta-derian* in Sokadana (S.-W. Borneo) and E. Sumatra, *gutta-percha* in Malaysia generally, *gutta-taban* in the Riou Archipelago, and *ngiato-mera* or *-to-oen* in Borneo; *Isonandra dasyphylla* [*Bintang*], is the *ngiato-bintang*; *I. Motleyana* is *kotian*; *I. macrophylla* is *ngiato-puti*; *I. Benjamina* is *ngiato-wangi*; *I. xanthochyma* is *ngiato-renkan*; *I. quercifolia* is *ngiato-tinang*; *I. rostrata* is the *ngiato-pisang* of Banka; *Dichopsis Krantziana* [*I. Krantzii*] is the *thior* of Cambodia and *chay* of Annam; *Chrysophyllum rhodencurum* is *karetandjeng*; *Cocosmanthus macrophyllus* is *karetmondjeng*; *Ceratophorus* [*Azaola*] *Leerii* is *balam-tandok*, *-tjabe*, *-trong*, or *-sonte*, or *kolan*; *Ceratophorus longipetiolatus* is *benko*; *Sideroxylon attenuatum* is *balam-tima* or *karet-pantjal.* He identifies *ngiato-dokang* as a *Bassia sp.*; and further enumerates as guttapercha-yielding plants *Bassia sericea*, *Isonandra lamponga*, *I. microphylla*, and *I. acuminata.*]

Commercial guttapercha is essentially *gutta-taban*, derived from *Dichopsis* [*Isonandra*] *Gutta*, of which there are a white-flowered and a red-flowered variety in Perak, known locally as *ngiato-puti* and *ngiato-mera.* The supplies from this species are supplemented by some of those previously mentioned; according to Burbidge, the guttapercha obtained from the Lawas district of Borneo is formed of the mingled saps of at least 5 species of *Dichopsis*, the juices of a *Ficus*, and of one or two species of *Artocarpeæ* being not infrequently added as adulterants. The *Dichopsis* [*Isonandra*] *spp.* flourish best in light rich loam with a rocky subsoil. Many of the most valuable varieties are confined to the hill-slopes at a distance from the sea, each forming a distinct grove of 200–500 trees. Small plants (1–8 ft.) of *D.* [*I.*] *Gutta* are abundant on the granitic formations in Perak up to 3500 ft.

All species are difficult to propagate, except from seed, and are very slow (25–30 years) to attain maturity. For their cultivation, it is recommended to take plants not more than 1 ft. high from the jungles; it is necessary to lift them very carefully, as they have long tap-roots, which are liable to be broken or injured, thus greatly retarding the growth of the plant, or killing it outright. These facts need to be taken into consideration in view of the rapid extermination of the trees which is now taking place. Doubtless large quantities of guttapercha, as of indiarubber, are still to be derived from the little-known interiors of Malacca, Borneo, and Sumatra, if at an increased cost; but cultivation, and some system of obtaining the product short of killing the tree, will have soon to be adopted in earnest, if a supply is to be maintained.

In Perak, the guttapercha trees are most abundant on Gunong Meeru, Gunong Sayong, and Bujong; a few large trees still exist on Gunong Babo and the Thaipeng range. In Borneo and Sulu, the Kadyans and their Murut neighbours collect considerable quantities of the gum in the surrounding forests, and convey it to Labuan for sale. A writer in the 'Journal of the Indian Archipelago' some years since says:—"To the north, the gutta collectors have reached as far as Perak on the Peninsular side of the Straits of Malacca . . . and, on the Sumatran side, as far as Pane and Bila. To the south, the whole of the Johore Archipelago, and the adjoining countries on the E. coast of Sumatra, as far as Palembang (including the forests on the Kampar, Indragire, Tunkul, Rite, Jambi, and Palembang rivers) now furnish *taban*. On the E. coast of the Peninsula, the knowledge of it has not yet advanced beyond Pahang. To the eastward, it has reached some of the rivers of Borneo, such as Brunei and Sarawak on the north, Pontianak on the west, and Koti and Passir on the east. It thus appears probable that the range of the *taban* embraces the whole of Borneo." Another author states that this tree is one of the most common in Johore. It is not found in the alluvial districts; but in undulating ground, such as that occupying the centre of the Malay Peninsula between the Indan and Batu Pahat, it occurs frequently, and, in some places, abundantly.

Generally, the collection of guttapercha is carried on immediately after the rainy season; in the dry season, the flow is very tardy, while during the rains, fever prevails, and the exudation is liable to be washed away. In Perak, no particular season seems to be recognized, and Murton was unable to learn whether the yield of the trees varies with the season; but he is of opinion that in wet seasons the guttapercha must contain more water, and need more boiling for its removal. The methods adopted for extracting the guttapercha vary somewhat among the Chinese, Malays, and Dyaks. The mature trees are felled just above the buttresses, by means of axes wielded by men standing on a stage 14–16 ft. above the ground; and the branches are immediately lopped off to prevent the sap ascending to the leaves. In Perak, the felling takes place at 5–6 ft. from the earth, and the top of the tree is also cut off at the point where it becomes too small for ringing. The ringing consists in making incisions in the bark of the felled trunk. The Binna people of the Malay Peninsula cut the bark with a *golo* (small knife) or *parang* (bill-hook) at distances of 6–18 in. apart, around so much of the trunk as is accessible while lying on the ground, at the same time removing about 1 in. of the rough outer coating of the bark on each side of the wound, but without peeling off any of the inner bark. The Malays of the same region strip off a ring of the soft bark about 1 in. wide in each case. In some districts, the bark is beaten with mallets, to accelerate the flow of the sap. The latter exudes for about an hour from each incision, and is caught in palm-leaves, coco-nut shells, and other receptacles, much, however, escaping to the ground and being lost. The extreme yields may be stated at 2 *catties* and 20 *catties* (of 1⅓ lb.) per tree, the average being 3–5 *catties*. The differences in yield are not readily apparent, as the trees are usually about the same age. The crude juice, if in small quantity, may be readily inspissated or concreted by rubbing between the hands. But this is rarely done, the rule being to boil the article in water in a *kwali* or iron pan about 15 in. diam. and 6 in. deep, with the addition of various adulterants. The boiling is done partly for the purpose of driving off the water which usually gets mixed more or less with the juice, and gives a stringy and deteriorated appearance to the guttapercha. Among adulterants other than the juices of allied plants, one of the most important is coco-nut-oil, to improve the appearance; lime-juice (1 pint to 3 gal.) has the property of coagulating the guttapercha immediately on ebullition. Generally in Borneo some 20 per cent. of scraped bark is added; indeed, it is said that the Chinese traders, who buy up the gutta from the gatherers, would refuse the pure article in preference for that containing bark, to which the red colour is mainly due. On reaching the export warehouses, the various kinds are assorted and sophisticated ready for commerce. The article is exported either in the form of balls weighing 13–20 *catties* (of 1⅓ lb.), or in large blocks, usually the latter for foreign ports.

The trade in guttapercha is of considerable and growing importance. Our imports of the raw article in 1880 were:—From the Straits Settlements, 62,862 cwt., value 505,821*l.*; other countries, 2994 cwt., 22,051*l.*; total, 65,856 cwt., 527,872*l.*, being an advance on previous years. Our imports from the Straits Settlements have increased from 19,665 cwt. in 1876, to 21,887 in 1877, 31,036 in 1878, and 49,387 in 1879. From Borneo direct, we received 22 cwt., value 350*l.*, in 1876, but none is recorded since. The exports of guttapercha and indiarubber combined from Borneo to Singapore in 1879 were valued at 437,027 dollars, or 91,047*l.* The proportion from each Bornean port was:—Brunei, 27,720 dol.; Labuan (received from the coast), 47,513 dol.; Sarawak, 361,794 dol. Of the figure for Sarawak, guttapercha represents 320,507 dol., leaving only 41,287 dol. for indiarubber. The little port of Sandakan shipped 6277 dol. worth of guttapercha. The exports of guttapercha from Java for the year 1877–8 were 1113 *piculs* (of 135½ lb.) to Holland, and 6 to Singapore; in 1878–9, 332 to Holland, 116 to Singapore, and 34 to England; crop of 1879, 555 to Holland, and 274 to Singapore. It has been estimated that the shipments of guttapercha from Sarawak alone during the years 1854–75 have totalled over 90,000 *piculs* (of 133⅓ lb.), representing the destruction of at least 3 million trees. Our re-exports of guttapercha in 1880 were:—4524 cwt., 53,949*l.*, to Germany; 1796 cwt., 16,100*l.*, to Holland; 1137 cwt., 13,541*l.*, to the United States; 1072 cwt., 4604*l.*, to other countries; total, 8529 cwt., 88,194*l.*

The physical and chemical properties of guttapercha, and its industrial applications, have been described in a section of the article on Indiarubber Manufactures, pp. 1162–4. It may be added that while exposed to the air and alternations of temperature, it oxidizes and decays rapidly, lasting only about 10 years on telegraph wires suspended in tunnels, but about 20 years when enclosed in iron pipes; yet in the sea, 20 years' exposure produces no visible deterioration.

The approximate London market value of guttapercha is 6*d.*–3*s.* 6*d.* a lb. for genuine, and 3*d.*–2*s.* a lb. for re-boiled.

Guttashea.—This name has been conferred upon a substance, somewhat resembling guttapercha, found in appreciable proportion (½ per cent.) in shea-butter (see Oils and Fatty Substances, p. 1410). Beyond what is there stated concerning it, Dr. Letts, who experimented upon the substance for Thomas Bros., Bristol, obligingly writes as follows:—"I did not succeed in isolating from the gum any very definite product. To the best of my recollection, the portion soluble in ether separated gradually as an almost colourless solid, but I could not determine whether or no it was crystalline. I remember that I could get no definite salts or other compounds from either it or the insoluble residue. The only other fact I considered of importance was the odour which the gum evolved on dry distillation, which was exactly like that of indiarubber (when heated). This led me to think that the gum might be allied to caoutchouc." It has been separated in a manner to admit of its industrial utilization, but no application has yet been found for it.

Hardwickia balsam.—An important oleo-resin is obtained from *Hardwickia pinnata*, a large tree, very common in the dense moist forests of the S. Travancore ghats, and found also in S. Canara. The method adopted by the natives for extracting the balsam is parallel with that current in Brazil for procuring copaiba (see pp. 1639–40). The product is a thick, viscid fluid, bearing the closest likeness to copaiba, from which it may, however, be distinguished by the tests given on p. 1640. It is used medicinally in India as a most efficient substitute for copaiba.

See also Gurjun, p. 1651.

Hog.—The term "hog-gum" (which must not be confounded with the inferior tragacanth bearing the same name, see p. 1686) is applied in Jamaica to a yellow resin resembling Burgundy pitch in appearance, which escapes as a pellucid juice from incisions in the trunk of *Moronobea coccinea.* It is used for making pitch plaisters and as a substitute for copaiba in Jamaica. In Brazil and Guiana, where it is known as *mani* or *oanani*, it is converted into torches, and employed in pitching boats.

Indiarubber (Fr., *Caoutchouc*; Ger., *Kautschuk*).—The term "indiarubber," often and conveniently shortened to "rubber," is applied to a large class of inspissated plant-juices, chiefly yielded by the species named on pp. 1627–8. In England, the name "caoutchouc" is restricted to the hydrocarbon which constitutes the main ingredient of commercial rubbers. The plan on which the present article is framed is to commence with a description of the origin and production of the commercial rubbers in their alphabetic order—African (including Mozambique, Madagascar, Liberian, &c.); Assam, Java, Penang, and Rangoon; Central American (including Cartagena, Guatemala, Guayaquil, Honduras, Mexican, Nicaragua, and W. Indies); Para; Pernambuco or Mangabeira—following with other kinds which as yet have no industrial importance, and concluding with statistics of production, export, price, &c. The industrial applications of the rubbers have already been described in the article on Indiarubber Manufactures, pp. 1142–64.

African.—Much ignorance still prevails concerning the sources and collection of the African rubbers. The Mozambique and Madagascar kinds are obtained from the climbing shrubs *voà-héré* or *voa-canja* (*Vahea madagascariensis*), *voà-hiné* (*V. comorensis*), and *V. gummifera.* The product of one of these species is said to be much superior to the others, but all are mixed indiscriminately by the natives. The preparation consists in treatment either with salt water or artificial heat. The Mozambique article occurs in orange-like balls; in "sausages," formed of slender strings of rubber wound upon a stick, which is finally withdrawn; and occasionally in smooth pieces of various size, termed "cake" or "line." The Madagascar sort consists of shapeless lumps, the better quality having a pink colour, and the lower a black.

Some rubber is produced in Mauritius by *Cryptostegia grandiflora*, and some by *Willughbeia edulis*, the latter found also in Madagascar, Chittagong, and Silhet.

A belt of rubber-yielding plants of different species extends across Tropical Africa from ocean to ocean. Within 20 miles of the coast from Liawa and the Lindi estuary (Masasi and Rovuma, E. Africa, 11° S., 38° E.), the forest becomes almost entirely formed of indiarubber vines, affording an abundant supply of fine rubber, at present gathered only in a very desultory manner by the natives, who gash the plants, and collect the exuding juice, which issues in a liquid form, and dries hard after short exposure to the air. Rolled into orange-like balls, it is taken to Lindi, where it is purchased by the Banyan merchants at about a quarter its value. Dr. Kirk has determined the plant which yields the best E. African rubber, and has obtained seeds of the species for introduction into India. It occurs in great abundance along the newly-made road from Dar-es-Salaam, in a W.-S.-W. direction, for about 100 miles towards the interior of E. Africa, through the Wazamaro country; it is apparently but little affected, except in the immediate neighbourhood of the villages, by the reckless mode of tapping employed. In many parts, a native can still collect 3 lb. of rubber daily. There are five species, but only one is considered worth tapping. Specimens received from him at Kew have been named *Landolphia florida* and *L. Kirkii*, the latter of which yields the best rubber. The *Landolphia* vine is known from Pangani inland all the way to Handei (in Usambara, E. Africa); at Magila, the rubber is made into balls for export. Dr. Kirk states that *L. owariensis* is common along the maritime region of E. Africa, and abundant at the mouth of the Zambesi, being found largely at Shupanga on that river at 100 miles from the coast. The produce of this has been shipped from Quillimane for America. The natives of the Marutse-Mabunda empire, on the Upper Zambesi, trade in rubber with the tribes to the west. The district called Mungao, extending from S. lat. 9° 25′ to Delgado in 10° 41′, yielded 90,000*l.* worth of rubber in 1877, when the industry had been only 3 years in existence. In 1878, Kilwa and Mombasa added largely to the supply. On the Victoria Lake, are one or two kinds of tree producing rubber of good quality. Rubber plants grow on the slopes of the Cameroons mountains (W. Africa), but the people do not yet know their value. Rubber trees abound on the river Djour, in the province of Bahr el Ghazal.

The *Landolphia spp.* are principal among the rubber plants of W. Africa. The rubber is collected from *L. owariensis*, extending from 10° N. to 10° S. on the coast of W. Africa, and most abundant in the highland districts of Angola; *L. florida*, frequent in inner Angola up to 1500–2500 ft., and in Liberia; and *L. Heudelotii* in Senegal. According to Speke and Grant, the natives say that the best rubber is produced by *L. florida*. The plants of this genus are woody climbers, growing well in damp rocky ravines scarcely available for other culture. Being climbers, they could not be grown in separate plantations, but would probably flourish in any tropical jungle, where trees already existed for them to ascend. Every part of the stem exudes a milky juice when cut or wounded, but this will not run into a vessel placed to catch it, as it dries so quickly as to form a ridge on the wound, which stops its further flow. The blacks collect it by making long cuts in the bark with a knife, and as the milky juice gushes out, it is wiped off continually with the fingers, and smeared on their arms, shoulders, and breast, till a thick covering is formed. This is peeled off their bodies, and cut into small squares, which are then said to be boiled in water. According to other accounts, the natives cut off a piece of the bark, and the milky juice is allowed to run into holes in the ground, or upon leaves. In some districts, they simply let the juice trickle down their arms, going from tree to tree till sufficient has accumulated, then peeling it off from the elbow in the form of a tube. Elsewhere, it is said to be collected and left to inspissate in wooden vessels. Collins remarks that, if the incisions be allowed to penetrate too deeply, they liberate a gummy substance, which, mingling with the rubber, depreciates its value. These vines may be tapped for rubber when 3 years old. Christy suggests their cultivation in plantations, and annually cutting down the young shoots almost to the ground, then crushing the stems between rollers, and treating the whole mass with carbon bisulphide, which dissolves the rubber, but not (he says) the injurious gummy matter. The rubber of these vines is of fairly good quality when carefully prepared. It should be made in separate sheets or cakes, 1–2 in. thick and 6 in. or so in diameter. Iron or stone vessels are superior to clay for collecting the juice. The better kinds are said to be prepared with the addition of 3 per cent. of strong liquor ammoniæ. When any liquid is added in the preparation, the sheets must be very thin, to facilitate drying. This question of drying seems to have much to do with the quality of the rubber, and the inferiority of African to Para rubber is largely attributed to its being sent into commerce in a raw, green state, whence possibly also arises its disagreeable odour, generated by decomposition. The desirability of introducing the *Attalea excelsa*, for the purpose of employing its nut (the *urucuri*) in curing African rubber, as in Para (see p. 1661), has even been discussed; but the slow smoky fire from any oily nut would probably have the same effect.

Another important W. African plant is *Urostigma Vogelii*, with possibly some other species. The tree (20–30 ft.) grows near the sea, at elevations of 50–60 ft., but does not flourish in marshy ground. The natives pollard the trees at 10-12 ft., and cut back the branches, thus obtaining a free and regular flow of sap. The cuttings are easily propagated, and grow vigorously. The trees are tapped at about 5 years, by making slashes or incisions in the trunk; the juice is collected in vessels, inspissated by the use of acids, and made up into balls the size of a large orange. Though often sent in a dirty state, the rubber is of good quality, and said to be the best of the Liberian. The juice obtained from trees less than 5 years old is watery, and does not afford such good rubber. Christy considers this a desirable species for cultivation in the lowlands of S. India, Ceylon, Java, Sumatra, Penang, and Siam.

A considerable proportion of W. African rubber is obtained from a plant which Holmes has determined to be *Tabernæmontana crassa*. In Senegambia, the *anjouan* (*Vahea senegalensis*) contributes to the supply. In Sierra Leone, rubber is collected from *Ficus Brasii*; and some *Ficus spp.* yield it in Angola on the W. coast, and at Inhambane on the E. A specimen of rubber from the W. coast of Africa is attributed to an undescribed species of *Carpodinus*; and in Réunion, some is said to be derived from *Periploca græca.*

The rubbers sold under the general name of African, omitting Mozambique and Madagascar, occur as shapeless lumps ("knuckles") from the Congo; "negroheads" or "balls" of scrap, and smooth cakes, from Sierra Leone; "thimbles," "nuts," and "negroheads" from the Portuguese ports; "tongues" from the Gaboon; and "balls" from Liberia. The African rubbers are more adhesive and less elastic than the Para article, and command a lower price; the inferiority could be much reduced by an improved system of preparation.

ASSAM, JAVA, PENANG, AND RANGOON.—Assam rubber is derived almost entirely from *Ficus elastica*, a small portion being obtained from *Urostigma laccifera.*

Ficus elastica grows wild along the foot and in the low tropical valleys of the Himálayas, from the Mechi River on the Nepal boundary at 88° E. long., to the extreme eastern limit of Assam, in 79° E. long., as well as along the feet and in the valleys of the southern mountains of the Bramaputra valley, viz. the Patkye, Naga, Khasi Jynteah, and Garrow Hills. It is not abundant until east of the Bor Nuddi, where it is common in the forests at the feet of the hills in the Khaling, Buri-goma, and Kuriapara Duars, between the Bor Nuddi and Mura Dunsiri Nuddi; the rubber has been exported from these forests, which extend over about 40 sq. miles, as well as from the low valleys of the Bhutan Hills, immediately above them, and especially from the forests in the neighbourhood of the exit of the Nunai Nuddi in the Khaling Duar and the adjoining hills, and those between the Dimjany and the Ruta Nuddis. In the Chardwar forests, between the Mura Dunsiri or Ruta Nuddi and Borali River, the plant is abundant. Between the Bilsiri and Goboru Nuddis, it is found as far as 16 miles from the hills, but the drier climate renders the produce much less plentiful. In the Nowdwar forests, where the climate is less moist, only the rubber obtained from trees close to the hills is good. In the Chydwar forests, the trees are found only immediately along the foot of the hills. The plant may be seen in parts of Sikkim, in the moist but rocky side-valleys of the torrents that feed the Teesta and Mahanadi rivers. It is also very abundant in the moist forest of the northern rainy zone of Burma, beyond British territory. It flourishes best in a very moist climate and a mean temperature of 98° F. in the shade, but will not endure stagnant water about the roots.

The collection of the rubber in Assam is conducted under rigid restrictions in the case of all trees growing in the timber reserves, but cannot be enforced in the case of scattered trees. Immense forests of the trees existed on both banks of the Subansiri river, and on other streams, but the reckless treatment they received from native lessees of the forests caused their ruin. In 1876, the leasing of these forests ceased, but there is now little or no rubber left in the plains of the Lakhimpur district. It is estimated that the forest of Cachar could yield upwards of 2000 cwt. of rubber annually. One district in Assam, 30 miles by 8, is said to contain 43,000 trees, many of them being 100 ft. high. According to Murton, there is little doubt that this same plant, *Ficus elastica*, affords the *gutta-rambong* of the Malay Peninsula, produced in the interior of Perak and on the Patani side of the Peninsula.

The natives who tap the wild trees slash every part of them within reach with their *daos* or knives. The incisions on the lower part of the stem, and on the roots which run some 30–40 ft. on the ground, are 6–18 in. long, and are made diagonally through the bark and into the wood, in an elliptical form, measuring about 3 in. across the centre. The exudation from these wounds is received in holes dug in the earth, or in leaves folded conically; that from the smaller cuts on the upper branches is allowed to concrete on the spot. According to Collins, the yield of a tree in August is about 50 oz. of milk, giving 15½ oz. of rubber; sometimes the proportion of rubber falls so low as 10 per cent. He also observes that "during the cold season, October–March, the milk is scantier, but richer than in the warm weather, March–October." Mann finds the best tapping season in Assam to be February–April. Hunter states that the trees "yield most during the rains;" he adds that a high yield for the first tapping of a tree 18 in.–6 ft. in girth is 35–40 lb. of rubber, it is then allowed 3–4 years' rest, when a second but much smaller collection is made.

Markham asserts that the trees may be tapped at 25 years, and that after 50 years they will yield 40 lb. of rubber every 3rd year. Murton says that in the Malay Peninsula the milk is obtained from the large roots, which are tapped 10–12 times in a year; a *picul* (133⅓ lb.) is sometimes taken from a large tree, but the usual yield is about ½ *picul*. This kind is said to require no preparation for market, and to present the appearance of long strings irregularly welded together, the best quality being gummy-looking, of very firm texture, and reddish-brown colour, while the inferior qualities have a large admixture of bark, and are much drier, without the gum-like consistence of the better grades. In Assam, on the other hand, it is the "loaf" rubber obtained from the lower parts of the stem and roots that requires artificial preparation, while none is bestowed upon the produce of the smaller branches. The treatment consists in pouring the milk into boiling water, and stirring until it assumes sufficient consistence to admit of being handled without becoming clammy or sticky. The plan adopted by a European house at Tezpore is to run the milk into wooden bins 6 ft. sq., partially filled with water, on which the rubber floats after a time. The latter, while still liquid, is removed and boiled over a slow fire in iron pans 4–6 ft. diam., and 2–2½ ft. deep, 2 parts of water being added, and the whole stirred constantly. When coagulated, the rubber is removed with iron forks, pressed, again boiled and pressed, sun-dried, and washed over with lime.

The rapid destruction by the natives of the wild rubber trees in Assam has called forth efforts to establish their cultivation in regular plantations. That at Chardwar has an area of 80 sq. miles, some 700 acres being under cultivation already. In 1878, it was stated that the planting had scarcely emerged from the experimental stage, for though no doubt remained that the tree would grow luxuriantly in the locality chosen, there was much variation in the degree of success gained by the several methods of planting. The plants put out in cane baskets in the forks of trees, though alive and healthy, remained nearly stationary; and many of those simply planted in the ground also did badly, thus condemning these two plans. All those planted on low split stumps, in earthenware cylinders on low stumps of trees, on piles of wood put crossways and mixed with earth, and on small mounds of earth 2–3 ft. high, did remarkably well, drainage about the roots being ensured by these modes. It has been proved that the best cuttings do not transplant so well as seedlings, and that raising plants from seed will be the method of propagation to be chiefly depended on.

Assam rubber has a peculiar mottled appearance, and varies in colour from cream or flesh tints to bright pink or reddish; it is very glossy, and sometimes covered with a greyish-white film, which may arise from oxidation or from some foreign application. Its form is either that of irregular lumps ("slab" or "loaf") produced as already described, or "balls" of the unprepared stringy substance obtained from the smaller branches. The impurities (bark, sand, clay) often reach 35 per cent., especially in the "balls." It arrives in baskets made of split rattan, covered with gunny-sacking, and weighing about 3 cwt. each.

Java rubber is also obtained from *Ficus elastica*, according to De Vrij. It is prepared by allowing the milk to concrete in the incisions made in the tree. It closely resembles Assam rubber, but has a deeper tint, with occasional reddish streaks.

Penang rubber is presumably identical in origin, no evidence being forthcoming in support of Wallich's statement that it is afforded by *Cynanchum ovalifolium*.

Rangoon rubber is also attributed to a *Ficus*, probably *F. hispida*.

These three kinds may be classed with Assam rubber for all technical purposes.

Attention has recently been called by G. W. Strettell to a troublesome climbing "weed," *Urceola* [*Chavannesia*] *esculenta*, very common in the Burmese forests, as a valuable source of rubber. It is urged that its cultivation could be made highly profitable. Assuming the plants to be placed 30 ft. apart, 400 acres would contain 19,200 of them, which are estimated to yield 1 *viss* (3 lb. 2 oz.) each per annum, worth 20*l.* per 100 *viss*, or 3840*l.* It is supposed that the cost of starting the plantation would be trifling, not exceeding 8*s.* per acre per annum on the first 7 years, making a total for that period of 1120*l.* The further cost of tapping, pressing, and preparing the juice is placed at 12½ per cent. of the profits, leaving a nett asset of over 3000*l.* per annum. The milk is said to coagulate more readily than that of *Ficus spp.* The incision adopted by Strettell is arrow-like, and made on the sides of the stem. The rows of cuts are 3 ft. apart, and arranged to be in vertical lines. Funnels formed of the leaves of *Butea frondosa* are selected for catching the exudation. The best season for tapping is about the end of April; between October and March, circulation is slow and the milk is scarce, but during the rains, the milk is more watery and abundant.

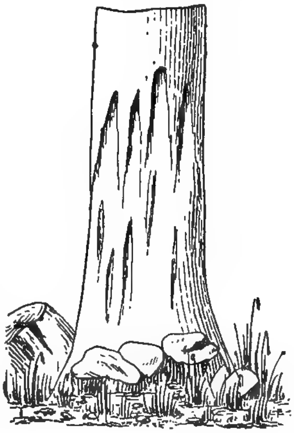
BORNEO.—The sources of Bornean rubber are not very accurately known. One authority names as the chief plant *Urceola elastica*, a climber with a trunk as thick as a man's body, and a soft thick bark, capable of being tapped at 3 years, and soon shooting up after having been cut down. Of this, Burbidge specifies 3 varieties, known respectively as *petabo*, yielding the best rubber, *menungan*, the most prolific, and *serapit*, giving the lowest quality. On the other hand, the *petabo* plant has been identified at Kew as a *Leuconotis sp.* Again, Burbidge himself more recently writes that the Bornean rubber or *gutta-susu* is the mixed saps of 3 species of *Willughbeia*, with the milks of 2 or 3 other plants surreptitiously introduced to increase the quantity; and he gives the Malay names of the 3 species as *manungan*, *manungan puti*, and *manungan manga*. Their stems have a length of 50–100 ft., and a diameter rarely exceeding 6 in. He adds that they are being slowly but surely exterminated by the collectors in Borneo, as throughout the other Malay islands, and on the Peninsula, where they likewise abound; on the other hand, they grow rapidly, and readily lend themselves to both vegetative and seminal methods of propagation, and hence are especially deserving of the attention of the Government of India, where they may reasonably be expected to thrive. The stems of these creepers are cut down to facilitate the collection of the creamy sap, being divided into sections measuring a few inches to 2–3 ft. long; the escaping milk flows into jars or buckets, the exudation being sometimes hastened by applying heat to one end. When sufficient sap has been thus collected, it is coagulated into rough balls by the addition of salt water or nipa salt (the latter obtained by burning the foliage of the *nipa* or *susa* [*Nipa fruticans*]). It reaches Liverpool in porous or spongy balls and shapeless lumps, internally white or pinkish, and saturated with salt water in such quantity as to cause a loss of 20–50 per cent. in weight on drying.

Burbidge remarks that there are many milk-yielding species of *Ficus* in the Bornean forests, which, with careful experiment, may possibly be made to contribute remunerative quantities. The Malayan representatives of the *Artocarpeæ* also deserve examination.

According to Murton, the *gutta-sing-garip* of the Malay Peninsula is identical with the *gutta-susu* of Borneo. There are two varieties of the plant producing it: one has a very dark-coloured outer bark, with lighter-coloured warts, and red inner bark; the other has a light cork-coloured outer bark, with longitudinal channels, and light-yellow inner bark. The produce of the former is considered superior. The stems are sometimes cut down, but are generally ringed at intervals of 10–12 in., and the milk is allowed to run into vessels made of palm-leaves or coco-nuts; the flow continues for some time, but after 10 minutes, the substance is very watery and thin. One plant will yield 5–10 *catties* (of $1\frac{1}{3}$ lb.) of coagulated rubber. When raw, the juice has the appearance of sour milk; it is coagulated by the addition of salt or salt water, and resembles Bornean *gutta-susu* in all respects.

Ceara.—The rubber known in commerce as "Ceara scrap" is produced by a distinct species from the other Brazilian and Central American rubbers, which has been named *Manihot Glaziovii*. It is a tree of 30 ft. in height, with a dense rounded crown, and attaining a diameter of 4–5 in. in 2 years. It grows wild in the flat country of Brazil running inland from the coast-town of Ceara, in 4° S. lat., mostly, so far as is known, at an altitude of about 200 ft. The district possesses a very dry arid climate for a considerable portion of the year; the rainy season lasts from November to May-June, when torrents of rain fall for several days in succession, followed by fine weather. There are years when scarcely any rain falls. The daily temperature averages about 82°–90° F. The soil frequented by the tree is sandstone, gravel, or granite, its dryness and poverty being indicated by absence of all ferns, weeds, grasses, and mosses.

1173.



The native system of bleeding the trees and collecting the rubber is sufficiently simple. The collector commences by sweeping away loose stones and dust from around the foot of the tree, and spreading some large leaves to receive the milk as it flows from the tree. The outer surface of the bark of the trunk is then stripped off to a height of 4–5 ft., as shown in Fig. 1173, and the milk exudes and runs down in many tortuous courses, a portion usually falling upon the ground. After several days, the juice becomes dry and solid, when it is pulled off in strings and rolled up in balls, or put into bags in loose masses. The paring should only be deep enough to reach the milk-ducts, which reside in the middle layer of the bark; but this circumstance is seldom regarded by the collectors, and many trees are prematurely destroyed by the careless wounding of the wood. The operation is conducted only during the dry season.

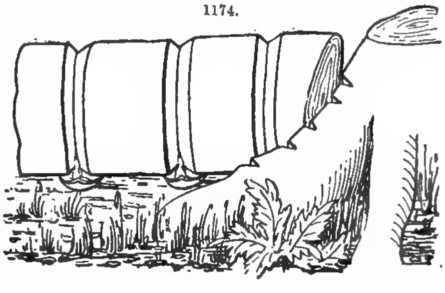
The habits and habitat of this plant immediately pointed it out for cultivation in a systematic manner in some of our warmer possessions, and the success attending the experiments is the more desirable since the late drought in Brazil caused the death of immense numbers of the tree. It has proved itself to be well adapted for culture in Ceylon, Upper India, Zanzibar, and Jamaica, but the climate of the Malay Peninsula is too moist for it. The experience gained thus far in its cultivation may be briefly stated. Seeds are early produced, if the tree is not shaded. They should be buried in brown sand, and kept moist until there are indications of growth, when they may be planted out permanently. In some situations, where the ground is rough and strong, they might be sown broadcast. Plantations may also be formed by cuttings, which take root as easily as a willow. They should be from the points of strong shoots, and about 1 ft. in length. In planting, each cutting may be put down in the soil to a depth of 6 in. If scarce, the entire shoot may be cut into pieces, each possessing a bud, all of which will grow if covered with ½ in. or so of soil. On loose sandy soils, or exhausted coffee land, plantations may be formed at little expense. Hard, dry, gravelly wastes, if found to support any kind of bush, are also suitable sites. Holes might be made in strong land with an iron jumper, and a stout cutting put into each, and filled with pebbles. On bare or thinly covered portions of rock, the cuttings might be laid down flat, and a little heap of stones, or any kind of débris, about the size of a mole-hill, piled over each, care being taken that the extreme point of each cutting with a bud is left uncovered. Wherever there is any sort of stunted tree or shrub vegetation, with an occasional sprinkling from a monsoon shower, the tree is likely to prosper. There can be no doubt of the hardiness of the species, its readiness of culture, and adaptability to circumstances. It grows quite as readily from seed as from cuttings, and, though a native of a tropical sea-level, thrives well in Ceylon up to at least a level of 3000 ft., and on the most barren soils. It would seem especially adapted for the dry and barren districts of the E. and N. provinces of Ceylon, or in the higher districts; but it would not be wise to risk it in localities where the temperature is liable to fall below 60° F.

The seed-coat is of remarkable thickness, and very hard, and the natural process of germination occupies, it is said, more than a year. All that is necessary to hasten this, is to assist the seed-coat in splitting, which is best effected by holding the seed firmly, and rasping off with a file both edges at the radicular end, recognized externally by possessing at its side a flat two-lobed appendage, technically known as the caruncle. It is best not to file off the actual end, as the radicle of the embryo may then be injured. After this treatment, properly performed, the young plant appears above ground in 2–3 weeks. The seedlings require no particular attention. They grow rapidly, and may be finally planted out at distances of 20 ft. The trees at Peradeniya (Ceylon) flowered at the age of 18 months; at 2½ years, the larger ones formed branching trees about 25–30 ft. high, with a stem 1 ft. 9 in. in circumference, at a yard from the base, and a smooth, silvery, birch-like bark, readily peeling off. The best system of tapping the trees under cultivation has yet to be proved. Some improved methods are described later on in the present article (see p. 1666).

This rubber is considered almost next to Para in value, being dry, very elastic, and free from stickiness; its one drawback of containing wood and other foreign matters, in such quantity as to cause a loss of often 25 per cent. in washing, may doubtless be altogether removed by the exercise of care in the collecting.

Central American.—The Central American, Cartagena, and Guayaquil rubbers are yielded chiefly by the *ulé* (*Castilloa elastica*), a lofty tree with a trunk 8 ft. diam., found in Mexico, Guatemala, Salvador, Honduras, Nicaragua, Costa Rica, Panama, the W. coast of S. America down to Guayaquil, and the slopes of Chimborazo, as well as in Cuba and Hayti. This extensive geographical range shows the tree to be capable of existing under considerably varied climatic conditions. The forests in which it grows are usually at or near sea-level, but it has been observed at an elevation of 1500 ft. on the Pacific coast. The soil is various, but the tree avoids marshy or boggy land, and manifests a preference for warm, deep loam or sandy clay, and it especially affects the margins of small running streams, where it occurs in little groups. A moist climate and high equable temperature are essential; the trees thrive best in dense, steaming, hot forests, and are particularly abundant where it rains during 9 months of the year, and the temperature ranges between 75° and 88° F. A second smaller species, *C. Markhamia*, also occurs in Panama.

1174.



In Panama, the usual method of collecting the milk is by felling the tree, and then making deep notches around the trunk at distances of about 1 ft. apart, as shown in Fig. 1174. Broad leaves placed beneath the notches receive the milk, which is afterwards collected in a large calabash or other vessel, poured into a hole in the ground, and thatched over with leaves, where it coagulates in about 2 weeks. Another plan is to bruise a handful of the leaves of the *Ipomœa bona nox*, and stir them about in the milk, which is thereby thickened in about an hour to a jelly-like porous mass, profusely exuding a black ink-like water when touched. The article thus produced is inferior. It is sometimes sliced into flakes 1 in. thick and sun-dried. In Nicaragua, it is found that though the tree yields the juice at all seasons, the best time for tapping is April, when the old leaves begin to fall and the new ones appear. During the rainy season, May–September, the richness of the juice diminishes. From that time till January, the rains decrease, the milk increases in richness, the tree prepares to flower, and the fruit appears in March, during which month and the succeeding one the milk contains the greatest proportion of rubber, the difference amounting to 60 per cent. more in April than in October. A tree about 18 in. diam. (probably 6 years old) tapped skilfully in April will yield some 20 gal. of milk capable of giving 50 lb. of rubber. This is a maximum figure, and the average is somewhat less. A tree of 20–30 ft. to the first branches is expected to afford 20 gal. of milk, and each gallon of milk to render 2 lb.–2 lb. 2 oz. of good dried rubber. By the Panama system of destroying the tree, the produce often amounts to 100 lb. of rubber from a tree. The Nicaraguan mode of tapping is as follows. The collector ascends the tree by climbers or a ladder as high as possible, and then commences a series of incisions with a sharp *machete* or axe in one of two ways. One is to make a long vertical cut, with diagonal cuts running into it, as in Brazil; the other is by encircling the tree with spiral cuts at an inclination of 45°; if the tree be large, two such spirals are made, either crossing or parallel with each other. At the bottom of the trunk, an iron spout is driven in, and the milk is received into iron pails. In the evening, the milk is freed from foreign matters by passage through a sieve, before transference to the barrels in which it undergoes coagulation. This last condition is brought about by the addition of plant-juices, notably that of the *acheté* (*Ipomœa bona nox*), as in Panama. The plant is collected, moistened with water, and bruised, and the juice, after straining, is added to the milk, in the proportion of 1 pint to 1 gal. After this operation, the rubber appears as a soft mass floating in a brown fluid, and smelling like new cheese. The mass is pressed under a plank or iron roller into a *tortilla* or cake, usually weighing about 2 lb. when dry, and representing 1 gal. of milk. When the *acheté* or other suitable plant is not procurable, water in the proportion of 2 to 1 is added to the milk, and the whole is allowed to stand for 12 hours. The residue which separates from the water is poured into underground vats and left to dry for 12–14 days. Sometimes the milk is simply poured on a prepared spot of ground, and the watery portion left to evaporate or disappear as it may; the rubber, when outwardly dry, is pressed to remove *bolsas* or bubbles of watery liquid. Slabs made in this way are sometimes called *méros*. The rubber which is allowed to dry in the iron spout conducting from the tree trunk is rolled into balls, and called *cabezza*; that which dries in the wounds on the tree is termed *bola* or *burucha*, and is esteemed in New York. The loss by drying (*merma*) is estimated at about 15 per cent. A recent traveller in Central America states that the *ulé* tree "yields many gallons every 2 years;" but in Panama, the tree is totally destroyed in obtaining the milk, and elsewhere the tapping is said to be so injuriously done as to be little better than immediate destruction.

There are several commercial varieties of the rubber obtained from *Castilloa spp.* Cartagena rubber arrives from New Granada (Colombia) in black sheets ⅜ in. thick, having a somewhat rough or "chewed" appearance, and more or less "tarry" or sticky. It also occurs in strips or scraps pressed together in bags. It loses about 35 per cent. of its weight on drying. Guayaquil rubber comes from Ecuador in large flakes and lumps, the better quality being whitish coloured, while the inferior is porous and saturated with a fœtid black liquid. Its loss by washing sometimes reaches 40 per cent. This and the preceding kind go chiefly to America. Nicaragua rubber, which mostly reaches the same market, loses only 15 per cent. by drying. The best of the Central American rubbers is that known as "W. Indian," not from its being produced in the W. Indies, but coming in steamers sailing thence. It consists of blocks which, in the first quality, are formed of thin separable sheets, and, in the second, of conglomerated "scraps" with fragments of bark. Honduras rubber is of good quality, and free from "tarry" matter. Guatemala rubber is one of the lowest and least regular kinds; the best specimens are whitish, while the "lower" are black and "tarry." This rubber arrives in sheets compacted together, whence a thick resinous fluid exudes on pressure; this fluid, on evaporation, leaves a hard resinous substance unaffected by steam.

The wasteful and destructive local methods of collecting the milk of this genus are causing its rapid extermination in the countries where it is indigenous. Attention has been directed to its naturalization in our tropical possessions, but though the plant is of rapid growth, it will scarcely thrive in regions that are not equally suited to the *Hevea spp.*, and its rubber is much inferior. It has been introduced successfully in Ceylon, Singapore, and Perak. With regard to its culture, it may be observed that trees in good situations will produce seeds early, but these need to be planted without delay, as drying destroys their vitality. Flowering occurs in January, and the fruits ripen in April (in Brazil). Stout branches, cut into pieces, each possessing a bud, and covered lightly with soil, will generally be found to grow. Strong cuttings 1 ft. long and furnished with buds, planted in the usual way, sooner develop strong plants. But the propagation of this tree is not reckoned so easy as that of the Ceara rubber (*Manihot Glaziovii*). In setting out young plants, the petiole or leaf-stalk of the lowest or oldest leaf should be buried in the soil; this simple device ensures the immediate and vigorous growth of the plant, and a symmetrical stem. When the planting leaves much bare stem above ground, the growth is slow, the plant long remains "leggy," and never forms a good tree. The plant has the curious habit of dropping its young branches, which disarticulate by a regular joint, and leave a clean scar on the surface of the stem. It is believed that after 6 years, the trees might be judiciously bled every 3 years.

PARA.—Para rubber, which is second to none in importance, is afforded by several species of *Hevea* [*Siphonia*], the most important being *H. brasiliensis*, *H. guianensis*, and *H. Spruceana*. These trees inhabit the dense, steaming forests on the Amazon and its tributaries, other species replacing them in some of the adjacent countries, e. g. *H. paucifolia* in British Guiana, where Prestoe believes it will be found in considerable abundance. Brazil is being gradually but surely denuded of its rubber-trees, collectors being now driven to the Tocantins, Madeira, Purus, and Negro rivers in search of supplies. A recent traveller states that, in Bolivia, extensive rubber forests are at present profitably worked on the Lower Beni, and it is natural to suppose that they exist to an equal extent on the Mayutata and Aquiry; those on the Mamoré and Lower Itenez, though giving rubber of a superior quality, do so in less quantity.

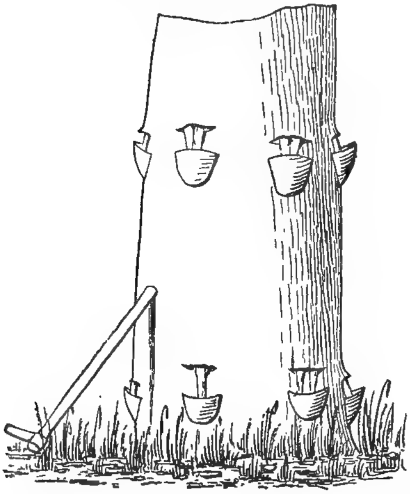
In the Para district of the Lower Amazon, the temperature varies between 74° and 95° F., the mean of the year being 81° F.; the supply of moisture is also very regular. On the Upper Amazon, the atmosphere is densely vapour-laden. The soil frequented by these trees is extremely rich mould. The trees will grow on the *terra firme* when planted, but their seeds naturally lodge in lowland swamps. All the species flourish best on rich alluvial clay slopes by the side of running water, where there is a certain amount of drainage; those growing on land which is periodically inundated (even to a depth of 5 ft.) are more prolific than those on very low or on elevated ground.

The methods adopted for tapping the trees are described at length by Cross. The collectors begin work immediately at daybreak, or as soon as they can see to move about among the trees. Rain often falls about 2–3 o'clock in the afternoon, so the tapping must be done early, as in the event of a shower, the milk would be spattered about and lost. The collector, first of all, at the beginning of the dry season, goes round and lays down at the base of each tree a certain number (3–12) of small cups of burnt clay. On proceeding to his work, the collector takes with him a small axe for tapping, and a wicker basket containing a good sized ball of well-wrought clay. He usually has likewise a bag for the waste droppings of rubber, and for what may adhere to the bottoms of the cups, these promiscuous gatherings being termed *sernamby*, and forming the "negro-head" of the English market. The cups are sometimes round, but more frequently flat or slightly concave on one side, so as to stick easily, when, with a small portion of clay, they are pressed against the trunk of the tree. The contents of 15 cups make about 1 pint. Arriving at a tree, the collector takes the axe in his right hand, and, striking in an upward direction as high as he can reach, makes a deep upward sloping cut across the trunk, which always goes through the bark, and penetrates 1 in. or more into the wood. The cut is 1 in. in breadth. Frequently a small portion of bark breaks off from the upper side, and occasionally a thin splinter of wood is also raised. Quickly stooping down, he takes a cup, and pasting a small quantity of clay on the flat side, presses it to the trunk close beneath the cut. By this time, the milk, which is of dazzling whiteness, is beginning to exude; if requisite, he smooths the clay so that the milk may trickle directly into the cup. At a distance of 4–5 in., but at the same height, another cup is luted on; and so the process is continued, until a row of cups encircle the tree at a height of about 6 ft. from the ground. Tree after tree is treated in like manner, until the tapping required for the day is finished. This work should be concluded by 9–10 o'clock in the morning, because the milk continues to exude slowly from the cuts for three hours, or perhaps longer. The quantity of milk that flows from each cut varies; but if the tree is large and has not been much tapped, the majority of the cups will be more than half-full, and occasionally a few may be filled to the brim. But if the tree is much gnarled from tapping, whether it grows in the rich sludge of the *gapó* (inundated land) or on dry land, many of the cups will be found to contain only about a tablespoonful of milk, and sometimes hardly that. On the following morning, the operation is performed in the same way, only that the cuts or gashes beneath which the cups are placed are made 6–8 in. lower down the trunks than those of the previous day. Thus each day brings the cups gradually lower, until the ground is reached. The collector then begins as high as he can reach, and descends as before, taking care, however, to make his cuts in separate places from those previously made. If the yield of milk from a tree is great, two rows of cups are put on at once, the one as high as can be reached, and the other at the surface of the ground; in the course of working, the upper row descending daily 6–8 in., while the lower one ascends the same distance, the rows in a few days come together. When the produce of milk diminishes in long-wrought trees, two or three cups are put on various parts of the trunk, where the bark is thickest. Although many of the trees of this class are large, the quantity of milk obtained is surprisingly little. This state of things is not the result of overtapping, as some have stated. Indeed, Cross believes it impossible to overtap a tree, if, in the operation, the wood is not left bare or injured. But at every stroke, the collector's axe enters the wood, and the energies of the tree are required in forming new layers to cover those numerous wounds. It has been supposed that the quality of the milk is better in the dry season than during the rains. In the rainy season, the milk probably contains a greater proportion of water; but, on the other hand, a larger quantity of milk then flows from the tree. No doubt the dry season is the most suitable for rubber collecting, although, wherever a plantation is provided with a preparing-house, convenient tapping may certainly be always carried on when the weather is fine. It is a common report that the trees yield the greatest quantity of milk at full moon. Even if this were found to be true, it would probably make little difference, as tapping must be carried on when circumstances are most favourable.

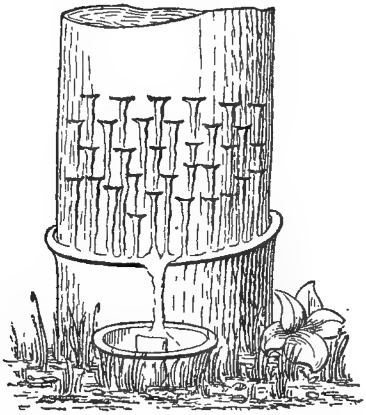
There are two other methods adopted in tapping, which are chiefly confined to the Upper Amazon and its tributaries. Both are exactly on the same principle, the materials used being only a little different. The loose outside bark of the tree is cleaned off to a height of about 3 ft. Beneath, a gutter or raised border of clay is pasted or luted to the trunk, enclosing one-half or the entire circumference. Cuts are thickly made in the bark above this, from which, the milk flows down to the gutter, whence it is conveyed to fall into a calabash conveniently placed. The other mode is by winding round the trunk the stout flexible stem of a climber, and claying it round securely so that no milk may escape between the trunk and the climber. These plans are not extensively adopted, and can only be successfully put in practice where the trees have not been previously tapped. There is always a great deal of "negrohead," the result of the distance the milk has to run, and of the large quantity of clay employed in the process. The respective methods are illustrated in Figs. 1175, 1176, 1177. Fig. 1178 shows the exhausted tree in a state of decay.

Going from tree to tree, the collector empties the contents of the cups into a large calabash, which he carries in his hand. As he pours the milk out of each cup, he draws his thumb or forefinger over the bottom to clean out some which otherwise would adhere. Indeed, a small quantity does remain, which is afterwards pulled off, and classed as *sernamby*. The cups, on being emptied, are laid in a little heap at the base of each tree, to be ready for the following morning. The trees occur at various distances (10–100 yd.) apart, and it is surprising that the natives have not yet seen the advantages that would be derived from forming plantations, whereby more than twice the quantity of rubber might be collected in one-fourth the time, and at far less cost and labour.

1175.

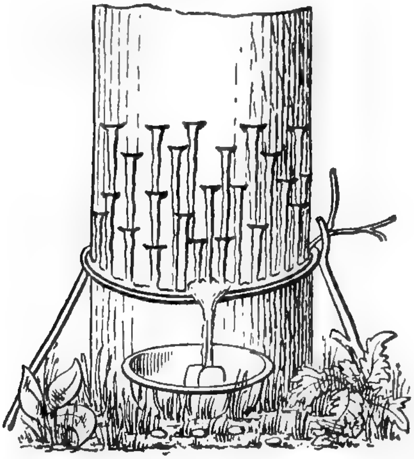


1176.

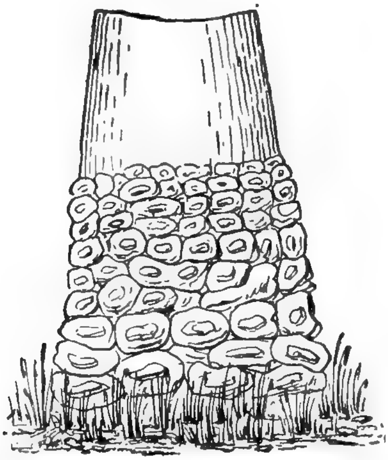


The common method of preparing the rubber is represented in Fig. 1179. The jars *a* are 18 in. high, and the bottoms are broken out. At the base, they are 7 in. diam., bulging out in the middle to 12 in., and narrowed at the mouth to a breadth of 2 in. Where a number of men are collecting for one master, much larger jars are in use. The milk, on being put into a large flat earthen vessel *b*, is placed on the floor in a convenient position. Adjacent thereto, the jar is set on three small stones, which raise it to 1½ in. above the floor. The narrow space between the base of the jar and the floor allows the entry of air, which causes a current of smoke to ascend with remarkable regularity and force. When the fire commences to burn strongly, several handfuls of nuts (preferably *urucuri* [*Attalea excelsa*], but failing them, those of *Euterpe edulis* and other palms), are put on, then some more wood and nuts alternately. The latter are dropped in at the mouth of the jar, until it is filled to within 4 in. of the top. Due care is taken that a sufficient proportion of wood is put in with the nuts. The mould *c* on which the rubber is prepared resembles the paddle of a canoe; in fact, at many places on the Amazon, this is the article most frequently used, if there is much milk, and the rubber is prepared in bulky masses. Occasionally the mould is slung to the roof, as the weight in handling it during the process would otherwise be very fatiguing. A little soft clay is rubbed over it to prevent the rubber from adhering, and it is afterwards well warmed in the smoke. The operator holds the mould with one hand, while with the other he takes a small cup and pours two or three cups of milk over it. He turns it on edge for a few moments above the dish, until the drops fall, then quickly places the flat side 2 in. above the jar mouth, and moves it swiftly round, as if describing the form of a cipher, with his hand, so that the current of smoke may be equally distributed. The opposite side of the mould is treated in the same way. The coating of milk on the mould, on being held over the smoke, immediately assumes a yellowish tinge, and although it appears to be firm on being touched, is yet found to be soft and juicy, like newly-curdled cheese, and to be sweating water profusely. When layer after layer has been repeated, and the mass ("biscuit") is of sufficient thickness, it is laid down on a board to solidify; in the morning, it is cut open along the edge on one side, and the mould is taken out. "Biscuit" rubber, when fresh, is often 4–5 in. thick. On being hung up to dry for a few days, it is sent to market. The rapid coagulation of the milk seems to be simply produced by the high temperature (about 180° F.) of the smoke. Cross thinks that with a strong current of heated air, or a good pressure of steam from a pipe, or by putting the milk in shallow vessels, and evaporating the moisture by the heat of boiling water, a similar result would be obtained. The finely divided

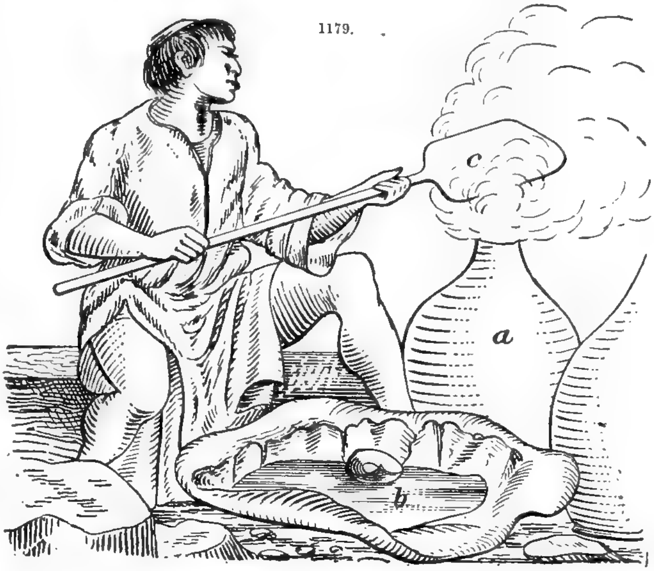
1177.



1178.



1179.



particles of soot which form a large proportion of the smoke undoubtedly absorb a considerable amount of moisture, although at the same time forming an impurity.

A more modern method of preparing the milk is by treatment with an aqueous solution of alum, and subjecting the coagulated mass to pressure, in accordance with Strauss' proposition. This plan is said to be in favour, as being capable of performance at a distance from the unhealthy locality where the milk is produced. The proportion of alum solution required is very small, but varies with the character of the milk. The latter should be previously strained free from extraneous matters. Coagulation ensues in 2–3 minutes. The rubber is then exposed to the air on sticks, and allowed to drain for 8 days. It is sometimes subjected to expression. The drawback of the process is the "wetness" which the rubber acquires from the presence of saline particles, which are never completely removed by pressing.

The excellent quality of this rubber has commended the plant to the attention of agriculturists in India and elsewhere. The result of experiments hitherto seems to be favourable to its establishment in Ceylon, Malabar, S. Burma, Zanzibar, and Jamaica, but not in Central and N. India.

The propagation and planting may generally be combined in one operation, the object being to reduce the expense, simplify and accelerate the work, and promote the more perfect development of the primary roots and trunk. The green-coloured terminal shoots of succulent growth, with the leaves fully matured, make the best cuttings. These should be cut off low enough, so that there is a joint at the base. When it is desirable to plant in dry firm land, a spadeful of soil should be turned over at each place, and the cutting planted in a sloping position. It should be covered with mould to within 3 in. of the point. The portion above ground should rest on the earth on one side of its termination, so as not to suffer during hot sunshine. In all stages, the crowns of the plants may be exposed to the rays of the sun. Plants intended for cutting stocks may be planted in open places, in the richest dark loam capable of producing a luxuriant rank crop of sugar-cane. Seeds might be planted out permanently at once, also in the same way as the cuttings. These would prosper much better if at the time of planting a handful of wood-ashes were added to the soil with each seed. Good ashes may be obtained by the burning of any description of green wood or newly-felled piece of forest. If the wood is allowed to rot before burning, almost the whole of the fertilizing principle will be found to have vanished. If stored in a damp place, the value of the product is diminished. For planting on inundated lands, the period of high flood should be preferred. Cuttings of greater length would be required in this case, the lower end of which should be sliced off in the form of a wedge. The workman could take a bundle of these, and, wading into the water, would plant at proper distances, but perfectly upright, taking care to push each cutting down deep enough in the soft muddy bottom, so that not more than 3–4 in. is above the surface of the water. The same rule would be applicable when planting in sludge or soft marsh land. The crowns of the cuttings must not, if possible, be put under water, as the young growths springing therefrom might rot. Seeds will not be found very applicable for planting in watery places or deep mud deposits. Some would come up, but a good many would mould and decay. In the varied course of circumstances and conditions, slight changes and modifications in the methods of working will no doubt suggest themselves.

Para rubber occurs in commerce in two forms:—"biscuits," prepared as described on pp. 1622–3, containing about 15 per cent. of water; and rounded balls of "negrohead," containing 25–35 per cent. of woody fragments, and other impurities. Occasionally an intermediate quality called "entrefine" appears. Adulteration is sometimes practised by the addition of the juice of the cow-tree or *massarandaba* (*Mimusops elata*).

PERNAMBUCO OR MANGABEIRA.—The *mangaba*, *mangabeira*, or *mangabiba* tree (*Hancornia speciosa*), a native of the high plateaux of S. America, between 10° and 12° S. lat., at 3000–5000 ft. elevation, affords a kind of rubber. The inhabitants of Pernambuco are now developing the supply of this article, which is collected by making oblique cuts penetrating the bark round the trunk, and attaching receptacles thereto. The juice is coagulated by Strauss' method (see above), and after 30 days' drying, is sent to market in cases and barrels. It occurs in the form of "biscuits" and "sheets." Like all rubber coagulated by saline solutions, it is very "wet," and does not rank high in value. It may be remarked that these trees do not seem to have suffered from the recent droughts in Brazil. Further, that the rubber might be much improved in quality by a better method of preparation.

OTHER RUBBERS.—There are a few other rubbers which are prepared as articles of commerce, but as yet scarcely known in British markets. "Palay" rubber is obtained from *Cryptostegia grandiflora*, a common plant on the coast of India. In Chittagong, it is furnished by *Willughbeia edulis* and *W. martabanica*. Sumatran rubber is yielded by *W. prima*, and is exported to Holland. Malacca rubber is ascribed to *Urceola elastica*. The rubber of the Malay Archipelago is attributed to *Alstonia costulata* and *A. scholaris*; and Fijian rubber is produced by *A. plumosa*. In N. Australia, rubber has been procured from *Ficus macrophylla* and *F. rubiginosa*; the latter is hardy, and has been recommended for culture.

Many other plants afford juices which coagulate on exposure, and bear more or less general resemblance to indiarubber. They may possibly be utilized when better known. They are chiefly as follows:—*Ficus anthelmintica*, the *cuaxinduba* of Brazil; *F. Doliaria*, the *coprub-uçu* of Brazil; *F. elliptica*, of S. America; *Cecropia peltata*, of Tropical America; *Artocarpus incisa*, the bread-fruit tree, in Malaysia and Oceania; *Galactodendron* [*Brosmium*] *utile*, in S. America, especially Venezuela; *Lactaria calocarpa* and *L. Moorei*, of New South Wales and Queensland; *Tabernæmontana spp.*, in New South Wales, Queensland, and Malaysia; *Plumaria phagædænica*, the *súcuúba* of Para (Brazil); *Cameraria latifolia*, in Cuba; *Gymnema lactiferum*, of Ceylon; *Chrysophyllum spp.*, of Brazil; *Sideroxylon spp.*, of Malaysia; *Kakosmanthus macrophyllus*, of Java; *Imbricaria coriacea*, of Mauritius, Madagascar, and Java; *Ceratophorus spp.*, of Malaysia; *Macaranga tomentosa*, of the E. Indies; *Sapium scoparium*, of the Antilles; *Hippomane Mancinella*, of Tropical America; *Euphorbia corollata*, in Canada.

Commerce.—The commerce in rubbers, which may be said to be a growth of the last 25 years, has now attained great importance. Our imports of indiarubber (termed "caoutchouc" in the Returns) were 158,692 cwt., value 1,536,660*l.*, in 1876; 159,723 cwt., 1,484,794*l.*, in 1877; 149,724 cwt., 1,313,209*l.*, in 1878; 150,601 cwt., 1,626,290*l.*, in 1879; 169,587 cwt., 2,387,947*l.*, in 1880. The imports of 1880 were contributed as follows:—Brazil, 76,466 cwt., 1,297,373*l.*; W. Coast Africa, foreign, 22,922 cwt., 276,741*l.*; Straits Settlements, 11,582 cwt., 114,989*l.*; Bengal and Burma, 10,264 cwt., 114,416*l.*; E. Coast Africa, 9382 cwt., 129,886*l.*; W. Coast Africa, British, 7271 cwt., 86,669*l.*; Aden, 6720 cwt., 84,780*l.*; British S. Africa, 4620 cwt., 42,653*l.*; Portugal, 3871 cwt., 55,804*l.*; United States, 3799 cwt., 48,039*l.*; Central America, 2440 cwt., 29,005*l.*; Holland, 1576 cwt., 17,269*l.*; Mauritius, 1550 cwt., 19,927*l.*; New Granada (Colombia), 1024 cwt., 12,165*l.*; other countries, 6100 cwt., 58,251*l.*; total, 169,587 cwt., 2,387,947*l.* Our exports in 1880 were as follows:—United States, 21,941 cwt., 282,894*l.*; Germany, 18,921 cwt., 269,086*l.*; Russia, 16,189 cwt., 261,252*l.*; France, 9920 cwt., 112,597*l.*; Holland, 7182 cwt., 101,068*l.*; other countries, 2579 cwt., 36,878*l.*; total, 76,732 cwt., 1,063,775*l.*

A review of the fluctuations in the supplies during the past 5 years shows the following facts. Holland sent us 2651 cwt. in 1876, 1059 in 1878, and 1576 in 1880. Portugal: 3329 in 1877, 2285 in 1879, 3871 in 1880. Portuguese W. Africa: 3881 in 1877, 1822 in 1878, 5248 in 1880. Portuguese E. Africa: 617 in 1876, 131 in 1877, 1497 in 1880. Fernando Po: 241 in 1876, 52 in 1877, 277 in 1878, 117 in 1879, 248 in 1880. W. Coast Africa: 16,841 in 1876, 9632 in 1878, 17,426 in 1880. E. Africa (native states): 1263 in 1876, 7855 in 1880. Madagascar: 32 in 1876, 83 in 1877, nil in 1878, 110 in 1879, 501 in 1880. Borneo: 15 in 1876, none since direct. Central America: 5425 in 1876, gradually falling to 2440 in 1880. Mexico: 62 in 1876, 291 in 1878, 50 in 1880. New Granada (Colombia): 3398 in 1876, gradually falling to 1024 in 1880. Venezuela: 521 in 1876, 354 in 1877, 710 in 1878, 482 in 1879, 986 in 1880. Brazil: 80,828 in 1876, 90,917 in 1878, 76,466 in 1880. Gambia and Sierra Leone: 2827 in 1876, 5641 in 1877, 3808 in 1879, 7104 in 1880. Gold Coast: 585 in 1876, 12 in 1879, 167 in 1880. Cape: 774 in 1876, 2120 in 1877, 1431 in 1878, 4620 in 1880. Aden: 2494 in 1876, 1254 in 1878, 6720 in 1880. Mauritius: 1790 in 1876, 570 in 1879, 1550 in 1880. Bengal and Burma: 12,990 in 1876, 9260 in 1878, 10,264 in 1880. Straits Settlements: 7615 in 1876, 5436 in 1878, 11,582 in 1880.

The exports of Bornean rubbers are included under guttapercha (pp. 1653–4). Of Brazilian ports, Ceara, in 1878, sent 40,377 *kilo.* to England, 258 to Hamburg, and 74 to Havre. Panama (in Colombia) sent 23,128*l.* worth of rubber to the United States in 1879. Costa Rica exported 27,854 lb. of rubber in the year ending Apr. 30, 1879; the quantities in previous years had been 57,213 in 1875, 59,427 in 1876, 90,576 in 1877, 78,231 in 1878; the shipments from the port of San José in 1880 were 11½ tons, 2078*l.* Ecuador exported 7059 *quintals*, value 24,707*l.*, in 1877; 6561 *quintals*, 22,963*l.*, in 1878 (of which, 5853 went to the United States, and 708 to England); 5594 *quintals*, 33,564*l.*, in 1879; 7995 *quintals*, 59,972*l.*, in 1880; in 1873, the exports were 16,365 *quintals*. Guatemala, in 1879, exported 1873 lb. to Belize; the value was 262 dol.; in 1877, the value was 2723 dol. The exports from British India were 15,893 cwt., 108,645*l.*, in 1875; 15,258 cwt., 97,861*l.*, in 1876; 13,308 cwt., 90,169*l.*, in 1877; 13,794 cwt., 89,381*l.*, in 1878; 10,033 cwt., 61,685*l.*, in 1879. The exports from the Lakhimpur district in 1871 were 260 tons, value 8340*l.* Assam exported 11,000 *maunds* (of 82 lb.) in 1873, and Sikkim 700. The exports from Java were 704 *piculs* (of 135½ lb.) for the 1876 crop; 15 to Holland and 10 to Singapore for the 1877 crop; 47 to Holland and 15 to Singapore for the 1878 crop; 135 to Holland and 58 to Singapore for the 1879 crop. The values of exports of rubber from Madagascar to Mauritius have been 37,458*l.* in 1873, 21,452*l.* in 1874, 14,539*l.* in 1875, 9770*l.* in 1876, 4672*l.* in 1877. The Venezuelan exports were 2545 lb. in British vessels, and 53,403 lb. in American, in 1878; and 27,563 lb. in American vessels in 1879. Mozambique exported 443*l.* worth in 1873, 22,198*l.* in 1876, and over 50,000*l.* in 1879; the figures have now probably reached their maximum, until roads shall have been made into the interior.

Values.—The approximate relative market values of the principal commercial rubbers entering

London are as follows:—Para, fine, 2–3*s.* a lb.; negrohead, 1*s.* 6*d.*–2*s.* 6*d.* Central American, 1*s.* 6*d.*–2*s.* 6*d.* Assam and Pegu, 9*d.*–2*s.* 6*d.* Other E. Indian, 1*s.*–2*s.* 6*d.* Madagascar and Mozambique, 1*s.* 3*d.*–2*s.* 8*d.*

Suggested Improvements in Collecting and Preparing Rubbers.—The time of year at which the sap ascends to the flowers has an effect on the quantity of rubber yielded. Too frequent tapping causes each successive yield to be less rich in rubber and more watery, and permanently injures the trees. Judicious tapping has no ill result. As to the manner in which the tapping should be performed, this will vary somewhat according to circumstances. Some remarks on tapping and barking other kinds of tree will be found under cinchona (see Drugs, p. 803), manna (see Drugs, p. 817), and maple-sugar (see Sugar); also under Copaiba, Gurjun, Peru, Tolu, Turpentines, and Varnishes, in the present article. The Brazilian plan of a perpendicular incision, with oblique tributary cuts on each side, has much to recommend it. Paring the bark, after the Ceara method, might also be advisable. The one great object to be kept in view is the avoidance of injury to the cambium layer. This is best effected by using an implement which is so made that it can only just remove or penetrate the bark sufficiently deep to reach the laticiferous vessels, residing mostly in the *mesophlœum* or middle layer of the bark. A modification of the knife used in marking standing timber, with the addition of a shoulder to adjust the amount of penetration, and a long handle, would probably meet all requirements. A clean cut, as opposed to a ragged one, not only heals readily, but keeps the product free from woody impurity.

The collected milk should be coagulated as rapidly as possible, for decomposition soon sets in, and materially modifies the character of the article. Some of the milks keep much longer than others without undergoing great change, but the collection of the day would always be best dealt with during the same day. It is undoubted that an effectual evaporative process for removing the water will produce a better article than any of the saline solution methods. A convenient form for the prepared rubber is thin (1–2 in.) sheets, which are easily packed into bales, and enable the amount of impurity to be readily arrived at.

Jalap.—See Drugs, pp. 814–5.

Jumrasi.—This gum has been doubtfully referred to *Elæodendron paniculatum*, a native of India. It occurs in roundish tears of variable size, the majority not exceeding ½ in. diam., externally finely rugose, and minutely cracked, with a shining fracture, rather brittle, some tears almost colourless, others dark reddish-brown, with intermediate shades of amber and brown. It is tasteless, and soluble in water, forming a tenacious sherry-coloured mucilage. It is not an article of commerce, but deserves attention with that view.

Jutahy-seca, or S. American Copal.—The so-called S. American copal is said to be a product of several species of *Hymenæa*, *Trachylobium*, and *Vouapa*, but the great bulk of it is undoubtedly derived from the W. Indian locust-tree, the *algarroba* of Panama, *jutahy* of Brazil, and *simiri* of Guiana (*Hymenæa Courbaril*). This tree is common in most parts of tropical S. America, attaining great size and age. From the bark of the stem, and from the roots, there exudes a resin bearing much resemblance to the animi of Africa (see pp. 1640–4). It is usually infested with insects; pale-brown, transparent, brittle, of agreeable odour, whence it is employed in fumigating and perfumery; its sp. gr. is 1·028–1·054, according to one authority, or 1·082, according to another; it is readily melted by heat, insoluble in water, but completely soluble in boiling alcohol. It is capable of application to varnish-making, like copal, and is universally employed in varnishing the native pottery. There is no evidence to show whether the 670 lb. of "*goma algarroba*" exported from Maracaibo (Venezuela) in 1880, and valued at 167½ dol. (of 4*s.* 2*d.*), was this substance or mezquite, which is also sometimes called *algarroba*.

Kauri, Kowrie, Cowdee, or Cawree (Fr., *Dammar austral, de la Nouvelle-Zélande*; Ger., *Kaurie-copal*).—This now familiar resin is afforded by several species of antipodean pines, chiefly *Dammara australis*, and in minor quantity by *D. ovata*, *D. Cookii*, and *D. lanceolata*, of New Caledonia, and *D. Brownii* of Queensland.

D. australis is now to be found growing only in the N.-W. peninsula of the N. island of New Zealand, between 34½° and 37½° S. lat., though the fossil resin is found embedded in the soil and in the coal-seams in various other parts of the colony, even so far south as Stewart's Island, showing that the tree formerly ranged over the whole colony.

The largest quantity of marketable kauri is dug out of the ground. It is found at various depths, from just above the surface of the soil to many feet below. It is found on bare hill-sides, on flat clay lands, in swamps, and even in some places that are covered with a more or less thick coating of volcanic débris. Sometimes the fossil resin is found in small detached lumps, and at other times large deposits occur in one hole. On cultivated land, it is not unfrequently turned up by the plough; and in many places, the cutting of drains in swamps has revealed large quantities. The implements used in digging for the fossil resin consist of a spade and a spear. The spear is a long steel rod, about ½ in. diam., with a wooden handle, like that of a spade or shovel. The rod is brought to a point, and the digger pierces it into the ground on the little knolls that indicate the probable sites of defunct trees. Practice and experience enable him to tell whether he is touching a stone or a piece of the resin. When he touches the latter, he digs around it until it is extricated, and then renews the search as before. The number of persons regularly engaged in digging varies from 1800 to 3000, the greater part of whom are Maoris, but even they do not show any special fondness for the work. They resort to it when they become pressed for food and clothing, on account of the failure of their crops, or other causes. Many Europeans have resorted to this kind of work, but they belong generally to the roughest class.

"Young" or recent resin is also obtained from the living trees, whence, at certain seasons, there exudes a yellowish-white liquid, of viscous consistence and pleasant odour, gradually hardening to an amber-like mass. In the forks of the large branches, deposits varying from a few lb. to nearly 1 cwt. are sometimes met with. When a kauri tree is cut in the bark, even one of the largest and oldest, varying in diameter from 6 to 10–12 ft., it will bleed like a young sapling. In a few weeks, if the weather be dry, a large mass of half-dried resin will have oozed from the wound, not unfrequently appearing in the form of a great thick band, reaching from the wound to the surface of the soil around the tree. When a tree is felled, the stump bleeds in a like manner, until large masses of resin can be broken off from the stump. This "young" resin is white in colour, and has not the rich amber hue which age imparts to it when stored beneath the surface of the soil away from the action of sun and weather.

When the fossil resin is taken out of the ground, it is covered with earth, and its surface is found to be in a partial state of decay. When the digger is tired of work, he puts his resin into a bag, and carries it to his tent or hut, and in the evening, or upon rainy days, he scrapes off the decayed surface until the clear solid gum beneath is reached. When a sufficient quantity of it has been scraped, it is put into a box or bag, and taken to the nearest store or public house, where it is sold for what it will bring. Sometimes the purchaser will assort it, but it is not generally assorted till it reaches the city buyer, who employs a large number of skilled hands for that purpose. The resin, after it is scraped and assorted, is packed carefully in boxes, so as to prevent the lumps from breaking. It is then ready for export. The dust and scrapings are also exported.

The total exports of the resin from New Zealand rose from 2850 tons in 1869 to 5054 in 1871, and fell to 2568 in 1874; in 1880, they were expected to reach 5500. More than ⅔ goes ultimately to the United States, being either shipped direct to New York and Boston in sailing vessels, or viâ London. Our imports rose from 36,514 cwt. in 1876, to 60,844 cwt. in 1880, from New Zealand alone; in the latter year, there were 2916 cwt. additional from other countries, the total being 63,760 cwt., value 192,658*l.* Some of the resin is used in New Zealand for varnish-making, and some of the "young" resin is consumed as a masticatory by the Maoris. The living forests are rapidly disappearing. The Government has taken no steps for their perpetuation, either by conserving or planting; and at the present rates, it is estimated that 50–80 years will see the bulk of the trees destroyed. The question remains, what amount of the fossil resin may be assumed to exist, but it is extremely difficult to form any correct opinion. Our re-exports of the resin in 1880 were 22,523 cwt., 62,133*l.*, to the United States; 3334 cwt., 11,941*l.*, to Holland; 2842 cwt., 10,227*l.*, to Germany; 2019 cwt., 7835*l.*, to other countries; total, 30,718 cwt., 92,136*l.* The approximate London market values are:—Packings and rough, 20–80*s.* a cwt.; scraped, 46–97*s.*; good to fine scraped, 55–122*s.*; selected, 115–200*s.*

Kauri occurs in commerce in large pieces; the fossil resin is usually pale-yellow or greenish-yellow, dirty-brown in inferior samples. The lustre is sometimes opaline; the fracture is conchoidal and vitreous; the odour is balsamic, and pronounced and characteristic in recently-broken or well-preserved pieces; the flavour is aromatic and pleasant; the sp. gr. of the New Zealand resin is 1·062–1·109, that of the New Caledonian is 1·119. It readily melts and dissolves in boiling alcohol, and in turpentine-oil; also in sulphuric acid, with a red colour. The Maoris burn it to obtain a fine black pigment from the smoke, and use it as a masticatory. In Europe and America, it is chiefly employed for making a varnish rivalling copal, and for giving a gloss to calicoes. Some of the finer specimens are made to replace amber in jewellery, but are less hard and more brittle. It has been used to some extent as a substitute for shellac in photographic varnishes.

Kino (Fr. *Kino*; Ger. *Kino*).—The term "gum kino" is applied to a class of astringent extracts of varied origin, none of which can accurately be called either resins or gums.

1. *E. Indian or Amboyna Kino.*—This is obtained from *Pterocarpus Marsupium*, a common tree in the Central and S. parts of the Indian peninsula, and in Ceylon; and a liquid kind from *P. indicus*, of S. India, Burma, Malacca, Penang, the Andamans, and Malaysia. The collection of the juice is effected in the following manner. A perpendicular incision, with lateral offshoots, is made in the stem of the tree when blossoming has set in, and a receptacle is placed at the foot of the incision. The exuding juice appears like red-currant jelly, but it soon thickens by exposure to the air, and when sufficiently dried, is packed into wooden boxes for exportation. It is one of the reserved timber-trees of the Government forests in Madras, and its juice is collected by natives, who pay a small fee for the permission. The hardened juice consists of blackish-red,

angular, pea-like grains, partially soluble in water, almost entirely in spirit of wine of sp. gr. 0·838, readily in caustic alkaline solutions, and largely in a saturated solution of sugar. The liquid kino produces a very inferior article on drying. The annual collection of kino in Madras probably does not exceed 1–2 tons. Its approximate London market value is 60–150*s.* a cwt. It is employed medicinally (see p. 815), and in the manufacture of wines, and might be employed as a source of tannin in dyeing and tanning, if sufficiently cheap.

2. *Butea, Bengal, Palas or Dhak Kino.*—This variety is afforded by the *palas* or *dhak* tree (*Butea frondosa*), common throughout India and Burma, and affording a dyestuff (see p. 867, Tisso), and a fibre (see p. 933), as well as by *B. superba* and *B. parviflora.* During the hot season, there issues from natural fissures and from wounds made in the bark of the stem, a red juice, which quickly hardens to a ruby-coloured, brittle, astringent mass. It occurs in small drops or tears, and in flat pieces which have been dried on leaves, and is almost always mixed with bark-fragments. It is transparent, freely soluble in cold water, and does not soften in the mouth. It is unknown in European commerce, but is employed in India as a substitute for the kind first described.

3. *African or Gambia Kino.*—This is derived from *Pterocarpus erinaceus*, a native of Tropical W. Africa, from Senegambia to Angola. The juice exudes naturally from fissures in the bark, but more abundantly from incisions, and soon coagulates to a blood-red and very brittle mass, known to the Portuguese of Angola as *sangue del drago* ("dragon's-blood"). It is practically undistinguishable from the official kind first described, but is not a regular article of commerce.

4. *Australian, Botany Bay, or Eucalyptus Kino.*—Several species of *Eucalyptus* afford astringent extracts, those from the "red," "white," or "flooded" gum (*E. rostrata*), the "blood-wood" (*E. corymbosa*), and *E. citriodora*, being quite suitable for replacing the officinal kind. It is chiefly obtained by woodcutters, being found in a viscid state in flattened cavities in the wood, and soon becoming inspissated, hard, and brittle. Minor quantities are procured in a liquid state by incising the bark of living trees, forming a treacly fluid yielding 35 per cent. of solid kino on evaporation. It is imported from Australia, but there are no statistics to show in what quantity.

Kos.—This name is applied in Ceylon to a yellow, viscid, milky juice obtained from the jack tree (*Artocarpus integrifolia*). While some accounts describe it as furnishing bird-lime, and therefore somewhat resembling guttapercha, others compare it with the babul variety of gum arabic (see p. 1632).

Wiesner describes a resin, which he calls "dammar selo," as a product of this species in Singapore. It occurs in fragments and masses, often containing woody refuse. Freshly-fractured pieces are sulphur-yellow. The sp. gr. is 1·099; the melting-point, 132° (269½° F.).

Lac, Gum Lac, Shellac, Stick Lac (Fr., *Laque*; Ger., *Lack*).—Lac is a resinous incrustation formed on the bark of the twigs and branches of various trees (all, it is believed, yielding more or less of a gummy, resinous, or saponaceous fluid) by the "lac-insect" (*Coccus Lacca*). The incrustation is cellular, deep-red or orange-coloured, semitransparent, hard, and breaking with a crystalline fracture. The substance is mainly formed by the female insects, which generally far outnumber the males. Each female inhabits a cell, and the incrustation seems intended to serve as a protection for her progeny. As soon as she is completely covered by the secretion, the female lays her eggs, and dies. The young, when hatched, work their way out through the body of the mother, eating the red substance with which her body is filled, and thus assuming the hue which gives them their value in dyeing. Having pierced the resinous incrustation, the young swarm on to the bark, and at once commence secreting lac. The insect never wanders from the branch to which it first attaches itself, and this, after affording nourishment to millions of the insect, decays; but the extinction of the species, which thus seems inevitable, is remedied by the frequency and distance to which the insect is transported by other insects and by birds. Artificial propagation is also now well understood, and described further on (see p. 1669).

The Indian trees frequented by lac, or on which it will attach itself, are very numerous. The following list is probably far from being exhaustive:—*Acacia arabica* and *A. catechu*, *Aleurites* [*Croton*] *lacciferum*, *Anona squamosa*, *Butea frondosa* and *B. superba*, *Carissa spinarum*, *Celtis Roxburghii*, *Ceratonia siliqua*, *Croton Draco* and *C. sanguiferum*, *Dalbergia paniculata* and *D. latifolia*, *Eriolæna Hookeriana*, *Erythrina indica* and *E. monosperma*, *Feronia elephantum*, *Ficus cordifolia*, *F. elastica*, *F. glomerata*, *F. indica*, *F. infectoria*, *F. religiosa*, *F. venosa*, and *F. villosa*, *Garruga pinnata*, *Gordonia floribunda*, *Inga dulcis*, *Kydia calycina*, *Lagerstrœmia parviflora*, *Mangifera indica*, *Mimosa cinerea*, *Nephelium Litchi*, *Ougeinia dalbergioides*, *Prosopis spicigera*, *Pterocarpus Marsupium*, *Schleichera trijuga*, *Shorea laccifera* and *S. robusta*, *Spathodea Rheedii*, *Tectona grandis*, *Terminalia tomentosa*, *Vatica laccifera*, *Vismia laccifera* and *V. micrantha*, *Zizyphus jujuba* and *Z. Xylopyrus*. The quantity and quality of the resinous secretion vary considerably according to the tree on which it is found. The best is confined to three trees, the *palas* or *dhak* (*Butea frondosa*), the *peepul* (*Ficus religiosa*), and the *koosum* (*Schleichera trijuga*). The last-mentioned tree is said to produce two crops annually (April–June, and October–December) in the Central Provinces of India, and its lac is reported to keep good for 10 years, while that of the others lasts 2 years only.

In India, lac occurs in Bengal and Assam (abundantly), the N.-W. Provinces and Oudh (sparingly), the Central Provinces (abundantly), the Punjab, Bombay, Sind, and Madras (more or less sparingly), and Burma (abundantly in some places). Lac is also found in some other countries of S. Asia,—Siam, Ceylon, some of the islands of the E. Archipelago, China,—Siamese lac being held in high estimation. In India, the best lac is obtained from Assam and Burma. The quantities produced and utilized vary greatly in different provinces, according to circumstances, certain forests being rich in lac, which has hardly been touched, owing to difficulty of access, and cost of carriage to the place of manufacture and port of shipment. In Bengal, lac is produced abundantly in the jungle tracts of Beerbhoom, Chota Nagpore, and Orissa. In various places in the forests of Assam, it is also found in large quantities, and forms a regular article of trade, a portion of the production being manufactured at Dacca, and the rest sent to Calcutta.

The lowest average yearly supply from the Pooroolia district in Chota Nagpore is 15,000 *maunds*, the actual yield being considerably more, and capable of great extension. From Singhboom, in 1867, about 1250 *maunds* of lac were exported. In the Gya district, the supply is estimated at 12,000 *maunds*; in Kamroop (Assam), about 5000 *maunds*, with great capacity for development; in Hazaribaugh, 2000 *maunds*. These figures probably do not by any means approximate to the actual yield of the districts named. In Bengal, lac is gathered twice a year—from mid-October to the end of January, and from mid-May to mid-July. In the N.-W. Provinces, lac is obtained in some quantities from the Garhwal forests; and, some years ago, was largely exported to the plains. It is probable that most of the lac now brought down from Garhwal is consumed in the local manufacture of toys and ornaments, and that very little, if any, is for exportation from Calcutta. In the Punjab, the production of lac is universal, but it is much inferior in quality to the lac of Central India or Bengal. In Sind, lac is only found in the forests about Hyderabad, 12 miles north and south, but in these abundantly. In the other forests of the province, it either does not exist at all, or in such small quantities that its collection does not pay. The cause of its occurrence near Hyderabad is worthy of investigation. It is found on the babool (*Acacia arabica*), and is gathered from October till April-May. This tree seems while in full vigour to be exempt from the attacks of the insect; it is chiefly infested when in the semi-dry state, and is not unfrequently killed outright. The lac produced in Sind is largely used in the manufacture of the well-known lacquered ware of Hyderabad. In Oudh, lac is gathered in the more wooded parts of the S.-E. districts (Roy Bareilly and Partabgurh) from various species of *Ficus*, especially *F. religiosa*. It is exported to the Mirzapore factories and elsewhere. Large supplies might also be procurable from the N. forests, but the collection might be unprofitable, owing to the want of manufactories within a reasonable distance. Government obtains half the produce in quantity or value from the gatherers. All the districts of the Central Provinces produce lac, but it is particularly abundant in the E. parts. Large quantities are consumed in the towns in the manufacture of bracelets and other articles, but most districts also export it to a greater or less extent. These provinces could readily supply 25,000 tons of stick-lac annually. Most of the lac produced in the Jubbulpore district is consumed in a European factory in the town. It also comes to Jubbulpore and Mirzapore in large quantities from Raipore, Bilaspore, Saugor, and Mundla. In Mundla, the right of collecting lac from the Government jungles has been leased to the owners of the Jubbulpore factory. In Sumbulpore, a Mirzapore firm (European) has for a long time practically held the monopoly of lac collection. Boorhanpore and Bombay receive supplies, though in small quantities, from the Nerbudda and Nagpore divisions. In the Hoshungabad district of the Central Provinces, the chief mart for lac is at Sobhapore, others of importance being Hoshungabad and Babai. Into Sobhapore, lac is imported largely from Bankheri, Futtehpore, and some of the hills on the other side of the Nerbudda, and from some of the jungles of the Nursinghpore district. Hoshungabad and Babai receive lac from the malgoozaree jungles and the hills beyond the Nerbudda, while it comes to Hurda and Seonee from the jungles of the Hoshungabad and Betul districts. The lac-collectors are mostly jungle tribes, who sell the produce in small quantities to Patwas, who again sell it in larger quantities to the regular dealers.

Much has been done in the Central Provinces of India in the way of propagating or cultivating lac. In forming preserves for this purpose, the first point to be considered is the species of tree which it will be desirable to utilize for the nurseries. The choice should fall (first) upon that or those found in greatest plenty, assuming they are adapted to the purpose, and (second) upon that which yields the best product. Of the trees previously named, the light-golden resin obtained from the *koosum* is the finest, as from it the most valuable orange shellac is manufactured; next in quality is that obtained from the *palas*, which yields the garnet lac of commerce. Wherever possible, therefore, the *koosum* tree should be chosen for standards; but as the *palas* is generally found in much greater numbers, area for area, its produce will nearly compensate in quantity for the reduction in its value.

Having selected the forest for experiment, the next point to fix on is the local date on which the insects leave the parent cells, a step of great importance, and one on which the first success of the plantation will very greatly depend; as, should the work of gathering brood lac be delayed until visible proof of the exit of larvæ is obtained, a vast quantity will be killed in the operations of collection, transport, and tying the encrusted twigs on the standards selected for the nurseries. The date of evolution having been fixed on with some certainty, twigs of that season's lac should be gathered about 15 days before, wrapped up in a few straws of grass, and attached to the trees selected for production, with threads of *palas* root fibre, or something else as easily obtained; each twig should be 9–12 in. in length, and be attached to the upper and middle branches of the tree. The grass tied round the twigs acts as a means of communication from the lac to the branches and leaf petioles, by which, many insects are saved that would otherwise die from want of nourishment, for, owing to the crookedness and irregularities of the incrustations, contact between them and the branches is seldom complete. It is also of importance to tie the brood lac to the upper and middle branches, as many of the lower ones, by this arrangement, become covered with insects, which are shaken or fall from above; whereas, if the lac be attached to the lower portion of the tree, many larvæ must fall to the ground and be lost. When attaching the twigs, it appears necessary to take care that the wood of the standard is not of denser composition than the wood of the tree from which the brood lac is gathered, as it is believed that the larvæ reared on soft-wooded trees are comparatively weaker than those which are found on species of harder texture. The brood lac yielded by the *koosum*, a very hard-wooded tree, appears best suited for propagating purposes, as it succeeds on trees of all other species. When several trees of the selected species grow together, it does not appear necessary at first to artificially cultivate more than ¾ of them, as, during the succeeding evolution, the remaining ¼ will almost certainly be brought under preparation by natural means; but as the success of the crop depends principally on the supply of juices obtained by the female insects during the period they continue to deposit the resin, it is necessary to place the brood lac on the youngest and most sappy branches.

Of the points to be noted in making preserves, the one of greatest importance, perhaps, is the fact that the lac incrustations may be plucked several days before the larvæ appear,—a knowledge of which will enable a larger number of trees to be prepared during one working season than if it was necessary to delay the operations until the evolution actually took place, as, owing to this latter being nearly simultaneous in and about one locality, the period for forming the plantation would be necessarily limited to the number of days it took for the cells to become empty; besides which, by attaching the lac twigs before the birth of the larvæ, great numbers are saved, which would otherwise perish during the process of being attached to the trees. Experiment has proved that the incrustations may be gathered 2–3 weeks before the exit of the young, by which, as before explained, much better results will be obtained than if it was necessary to delay the work until this event took place. The date of exit varies considerably in forests separated by comparatively short distances. These differences arise less from the latitudes of the forests than from certain local conditions. There is much reported variation in the number of evolutions, and consequently in the number of crops which are obtained, in different countries. In Mysore and Burma, it would appear that three evolutions take place during the year. In the Central Provinces, only one good crop in a year can be hoped for.

After the larvæ appear, they crawl about the stems of the plant in search of young juicy spots, from which, when once fixed by their probosces, they cannot be removed without fatal injury. The male and female are identical in size and shape, and both commence at once the formation of their cocoons by excreting a substance resembling lac, those of the males being ovoid or elliptic in form, while those of the females are more circular, and exhibit three distinct apertures arranged in triangular fashion in their roofs,—one being the anal aperture through which impregnation is accomplished, and the larvæ eventually swarm; the other two, those by means of which the insect obtains a supply of air. About ten weeks after birth, an important change has taken place in the larvæ; the female cocoons are completed, and the insects have assumed the final or imago state; as the female remains fixed in the position she first took up on the twig, the male is obliged to seek her, which he does by leaving his cell in a backward manner to the ventral aperture, and crawling on to the female cells, where he fulfils his office, and almost immediately after dies. This exit of male insects is a fact well to know, as, owing to the smallness of the animal and his superficial similarity to the original larva form, it is possible for a novice to mistake such an evolution for one of young larvæ, and to commence gathering the twigs under the impression that a new birth of the latter had taken place. If the lac is plucked before or immediately after impregnation has been accomplished, the females must perish from being cut off from their sap supplies, and, as a natural consequence, the young brood must be destroyed with them. Impregnation having been accomplished, the female busies herself in sucking up large quantities of vegetable juices, increases greatly in size, and begins the excretion of the true lac. The females must be attached to young twigs by which bountiful supplies of fluid will be supplied them, otherwise they will die, or never become fully developed, the lac cells will be small in consequence, and the eggs will suffer in number and condition. This no doubt is the reason why, in districts where the seasons are dry, and where showers are of unfrequent occurrence during the hot weather, the summer crop is invariably poor and scarcely worth collecting. Moisture is one of the great essentials for a fine crop of lac, and many disappointments result from fixing on dry arid spots for the formation of the plantations. The females cannot obtain sufficient nourishment at this period from the sapless stems, and their death will be recognized by the pitted appearance assumed by the cells, the crowns of which fall in as the insect contracts within them, and by the cessation of the growth or disappearance of the white filaments which obtrude from the spiracular orifices. Species such as *koosum* and *gooler* (*Ficus glomerata*), which most frequently are found growing along the banks of rivers, where the atmosphere is humid, are, for these reasons, especially adapted for yielding good crops of lac; while the *palas* offers advantages, as its sap-producing functions are actively employed during the hottest season of the year, when it forms both new wood and leaves.

Besides the damage brought about by fires, drought, and frost, which to some extent can be guarded against, there are other enemies to the crop which are still more difficult to contend with. Ants, both large and small, attend the female cells for the purpose of licking up the sweet excrement; they appear to hurt the insect by biting off the ends of the white filaments, and thus bringing many an occupant of the cells to a premature end by stopping the supplies of breathing-air, which the filaments serve to convey through the holes in the lac. Where ants are seen about the lac, it never appears healthy, and many cells are found with the insect dead inside them. The lac whilst on the tree is also attacked by the larva of a moth, which appears to be a species of *Galleria*. It eats the juicy females of the coccus, and bores through the lac cells; it is found both in the field and the store-room. A second species appears to belong to the genus *Tinea*. These insects destroy the colouring matter contained in the females, and also all hope of a brood of young from the cells visited by them. At present there seems to be no way of protecting the lac from their depredations. The ants, however, may be circumvented in two ways,—either by surrounding the trees with wood ashes, or with something sufficiently attractive to draw their attention away from the incrustations.

It seems possible, owing to the great drain made on the sap of the young branches by the insects, that considerable damage will be found to result to the trees on which they are propagated, and that it will be necessary at some future time to fix a limit to the continuous cultivation of lac on the same tree; at any rate, it will probably be found beneficial to both lac and tree if a regular system of pruning be carried out, to encourage the formation of young twig or branch wood.

In Mysore, lac is produced in all three divisions, but chiefly in Nundidroog, and is found most commonly on *Vatica laccifera*. The insect thrives well in Mysore, and it might by cultivation be raised to any extent on trees growing on barren soil which would otherwise yield no return. The carob tree (*Ceratonia siliqua*), which is about to be introduced into Mysore, will probably, if it will succeed in the province, be found well adapted to this purpose. It will flourish in dry and stony soil, and the lac insect seems to be much attached to it. The supply of lac in the province is large, and could no doubt be considerably increased. Apparently the lac produced in Madras and Mysore is consumed locally, for the exports from Madras are next to nothing.

The mode of propagation in Mysore is as follows:—The insects are applied to the branches of the trees (*Vatica laccifera*) 3 times in the year, the old branches with the insects on them being lopped off, made into small bundles, and tied up to fresh branches. The insects then begin to build their cells on the branches, and continue occupied for about 3 months. When this period has expired, the young leave their abode. This opportunity is carefully watched, the insects are secured for further use, and the lac-covered branches are gathered, each tree producing on an average 2½ *seers*. The insects are invariably applied to immature trees or saplings, as the old trees do not contain sufficient sap for their nourishment. It is as much artificially propagated, or cultivated, as any other raw material for manufacturing purposes. If it takes to a tree not considered suitable for elaborating the colouring matter and gum, it is removed thence, and placed upon others where it thrives better. In Central India, the application of "seed" to a new tree takes place in June for the November crop, and in October for the April crop. If the seed is placed on a congenial tree, the produce does not deteriorate from the same seed being left any time on the same tree, so long as the tree retains its vigour. It has been successfully propagated after a transport of some hundreds of miles.

The vast forests of British Burma are capable of producing an almost unlimited quantity of lac; but hitherto the largest portion of the quantity available for shipment has been brought from Upper Burma and the Shan States, and the principal market is found in Calcutta, where the rough stick-lac is manufactured into shell-lac for export. The product is, to a small extent, procurable in the hill tracts of Arakan, and with encouragement it is susceptible of development. Prizes have been offered to the people to stimulate the propagation of the insect, and State plantations have been formed at Toungoo, and Magayee, with success, while another at Sittang has quite failed.

The Padoung Karens, beyond the N.-E. frontier of Burma, carry on the production of lac upon a large scale, and in a systematic manner. In Assam, a small quantity of lac is produced in the district of Darrang. In some districts, the insect is artificially reared on the *jhuri* tree (*Ficus cordifolia*).

In its raw condition, incrusted around the twigs of the tree on which the insect feeds, lac is technically called "stick-lac." The twigs are generally, for convenience of transport, cut up in lengths of 2–3 in., and it is probable that a great deal of material is wasted in this process. The objects of the manufacturer are:—(1) To separate the resinous incrustation from the wood; (2) to free the resin from the colouring matter; (3) to convert the resin into what is known as "shell-lac"; (4) to form from the colouring matter cakes of dye known as "lac-dye." As generally practised, these processes are conducted in a primitive manner. The first step is to strip the twigs of their covering of lac, for which purpose, they are placed under a roller on a platform; the roller being rapidly passed over them, the coating comes off, leaving only a small portion adhering, which requires hand-picking for its separation. The wood is rejected. The separated lac is reduced by rolling or other simple means till it will pass through a moderately coarse sieve, say ¼-in. meshes. It is next placed in large tubs half-full of water, and is washed by coolies, who, standing in the tubs, and holding on to a bar above by their hands, stamp and pivot about on the heels and toes, until, after a succession of changes, the resulting liquor comes off clear. The lac (now "seed-lac"), having been dried, is placed in long cylindrical bags of cotton cloth of medium texture, and about 10 ft. long and 2 in. diam. These bags, when filled, are taken to an apartment where there are a number of *chulas*, or open charcoal furnaces. An operator grasps one end of the bag in his left hand, and slowly revolves it in front of the fire; at the same time an assistant, seated at the other end of the bag, twists it in the opposite direction. The roasting soon melts the lac in the bag, and the twisting causes it to exude, and drop into troughs placed below, which are often only the leaves of *Agave americana*. When a sufficient quantity in a molten condition is ready in the trough, the operator takes it up in a wooden spoon, and places it on a cylinder, some 8–10 in. diam.; sometimes the cylinder is of wood, the upper half being covered with brass; in some places, the freshly-cut, smooth, cylindrical stem of the plantain is used for this purpose; or the cylinder may be of porcelain, filled with some heat-absorbing material. The stand which supports the cylinder gives it a sloping direction away from the operator. Another assistant, generally a woman, now steps forward with a strip of *Agave* in her hands, and with a rapid and dexterous draw of this, the lac is spread at once into a sheet of uniform thickness, which covers the upper portion of the cylinder. The operator cuts off the upper edge with a pair of scissors, and the sheet is lifted up by the assistant, who waves it about for a moment or two in the air, till it becomes quite crisp. It is then held up to the light, and any impurities (technically "grit") are simply punched out of the brittle sheet by the finger. The sheets are laid one upon another, and, at the end of the day, the tale is taken, and the chief operator is paid accordingly, the assistants receiving fixed wages. The sheets are placed in packing-cases, and, when subjected to pressure, break into numerous fragments. In the fresh state, the finest quality has a rich golden lustre. These sheets and fragments form the "shell-lac" or "shellac" of commerce.

"Button-lac" differs from shellac only in form. Instead of being drawn over a cylinder, the melted lac is allowed to fall upon a plane, and assumes the shape of large, flat, gingerbread-nuts, about 3 in. diam. and ⅙ in. thick. The manufacture of lac-dye is described on pp. 861–2.

Elliott Angelo, of Cossipore, has adopted improved methods and machinery in his factory. The first of these is in the washing department, where steam-driven cylinders with internal rotating arms are used. The macerated seed-lac is melted in closed steam-heated vessels, with addition of rosin, which is said to act as a flux and a preventive of burning, and subsequently to evaporate. The cylinders for making shellac are formed of zinc, and maintained at an equable temperature by internal pipes supplied with tepid water. Lac is frequently adulterated with orpiment, which imparts a fine yellow colour; and very largely (up to 50–60 per cent.) with common rosin. The latter may be readily detected by its odour on breaking the mass. The chief grades are "fine orange D C," "liver," "garnet," "native leaf," and "button." The approximate relative market values in London are:—Orange, 65–200*s.* a cwt.; liver and native orange, 65–175*s.*; garnet, 60–155*s.*; button, dark to middling, 60–180*s.*; button, good to fine, 70–200*s.*; seed-lac, 80–90*s.*; stick-lac, Siam, 45–140*s.* In India, lac is used chiefly in the manufacture of various trinkets. In Europe, it is largely employed in the preparation of spirit-varnishes, cements, lithographic ink, and sealing-wax, and as a stiffening for hats. White shellac is usually kept in water, by which means, its capability for solution is preserved. This property is lost within a fortnight of its preparation, by exposure to the air; within the period, it is readily soluble in naphtha or "finish."

The trade in lac is extensive. Our imports of seed, shell, stick, and dye lac have been:—98,855 cwt., 530,017*l.*, in 1876; 100,442 cwt., 395,831*l.*, in 1877; 79,593 cwt., 273,923*l.*, in 1878; 51,159 cwt., 179,305*l.*, in 1879; 58,081 cwt., 369,317*l.*, in 1880. The imports of 1880 were contributed as follows:—Bengal and Burma, 54,179 cwt., 347,998*l.*; other countries, 3902 cwt., 21,319*l.*; total, 58,081 cwt., 369,317*l.* Our imports from Bengal and Burma fell from 95,058 cwt., in 1877, to 47,368 cwt. in 1879, and only recovered to 54,179 cwt. in

1880. Our imports from the Straits Settlements fell from 5228 cwt. in 1876, to 541 cwt. in 1879, and only recovered to 832 cwt. in 1880. Our re-exports in 1880 were:—To the United States, 14,389 cwt., 70,223*l.*; Germany, 10,458 cwt., 61,542*l.*; Holland, 4200 cwt., 23,336*l.*; Russia, 2801 cwt., 16,319*l.*; France, 2653 cwt., 17,946*l.*; other countries, 4124 cwt., 21,984*l.*; total, 38,625 cwt., 211,360*l.* It is necessary to repeat that all these figures include lac dye. The Indian exports, excluding lac dye, were:—68,264 cwt. in 1875, 92,915 in 1876, 109,661 in 1877, 95,075 in 1878, 83,162 in 1879. The relative proportions of the several kinds in 1875–6 were:—Shellac, 80,645 cwt.; stick-lac, 207 cwt.

There remains to mention under this head the discovery of the same or a very closely allied insect, capable of affording the same product, in some portions of the United States. The plants on which the insect has been found are *Acacia Greggii*, and the creasote bush, stinkweed, or etiontio (*Larrea mexicana*). These plants flourish abundantly from S. Utah to New Mexico, and from the Colorado Desert to W. Texas, wherever the rainfall amounts to 3 in. annually. The second species is particularly common on the hills bordering the Gila, and on the sandy wastes adjacent to Tucson and Camp Lowell, in Arizona. With care and cultivation, there seems to be no reason why these natural resources should not be developed so as to render America independent of foreign supplies of shellac.

Lignum aloes.—See Perfumes—Agar, pp. 1523–4.

Liquidambar.—See Storax, pp. 1682–3.

Mahogany.—The mahogany tree, *Swietenia Mahogani* (see Timber), under cultivation in Bombay, affords an abundance of a superior silvery-looking gum, of which no use seems to be made.

Mango.—On wounding the bark of the mango (*Mangifera indica*), which is common everywhere in India, there exudes a soft, reddish-brown gum-resin, hardening by age, and much resembling bdellium. It is often mottled in such a way as to lead to its confusion with asafœtida (the *hing* variety), or with amygdaloid benzoin. It has a strong and persistent odour of ripe mangoes, and emits a smell of roasting cashew-nuts when burnt in a candle-flame. It dissolves partially in water, and completely in spirit. It is used medicinally by the natives of India.

Mastic or Mastich (Fr., *Mastic*; Ger., *Mastix*).—The lentisc or mastic shrub (*Pistacia Lentiscus*) is a native of the Mediterranean coast region, including Spain, Portugal, Italy, Greece, the islands on the Turkish coast, Syria, Morocco, and the Canaries. Formerly the resinous exudation was collected from the plant in Cyprus, and experiment has proved that it might easily be obtained in some of the other members of the Archipelago, yet the production is now exclusively confined to the island of Scio (Chios). The mastic country of Chios is usually flat and stony, with little hills intervening, and few streams. The principal villages engaged in the industry are Calimassia, St. Georges (S. of Anabato), Nénita, Mesta, and Kalamoti, besides about a dozen of minor importance. The shrubs are about the height of a man. The bark of the stems and branches contains resin-ducts, which require but slight incision to provoke exudation. About June–August, the bark of the stems and chief branches is thickly scored with vertical cuts, the operation being renewed 3–4 times during the period. The exudation flows freely, hardens, and dries, so that about 15–20 days later it can be collected in little baskets lined with white paper or clean cotton wool. The ground beneath the shrubs is kept hard and clean, so that accidental droppings may not be spoiled. The small quantity spontaneously exuded by the lesser branches is of superlative quantity. A fine tree may yield a total of 8–10 lb., but a shower of rain during the harvest produces disastrous results; frosts are very injurious to the trees, but of rare occurrence. There are 4 qualities of mastic:—(1) "Cake" is composed of large pieces, and is considered the best by connoisseurs; it is sold chiefly for use in the seraglios, all Turkish women chewing mastic; its price is 120–130 *piastres* (of 2*d.*) per *oke* (of 2·83 lb.), and even more. (2) Large tears are ordinarily worth 90–100 *piastres*. (3) Small tears or pearls fetch 70–85 *piastres*, and are used industrially. (4) Mastic mixed with fragments of leaves and with sand is consumed in the manufacture of the Turkish liqueur called *raki* or "mastic brandy."

Mastic tears are pale-yellow or slightly greenish, the colour deepening with age; they are either dusty and opaque, or washed and glassy externally and transparent internally. They are brittle, with conchoidal fracture, and a turpentinous balsamic odour, and are readily distinguishable from sandarach by softening and kneading in the mouth. The sp. gr. is 1·04–1·07; the softening-point is 80°–99° (176°–210° F.), the melting-point, 105°–120° (221°–248° F.). The resin dissolves in half its weight of pure warm acetone, and slowly in 5 parts clove-oil. The medicinal use of mastic in Europe is a thing of the past, and the little that arrives here is employed in varnish-making. All the good qualities are consumed in the Levant. Chios exported 28,000 lb. "picked" and 42,000 lb. "common" mastic in 1871. The approximate London market value is 2*s.* 6*d.*–4*s.* 6*d.* a lb.

In the Indian bazars, another mastic is met with, which is afforded by *Pistacia cabulica* and *P. Khinjuk*, trees found growing all over Sind, Beluchistan, and Afghanistan. The better qualities much resemble Chian mastic—being sold as *mustagi-rúmí* ("Roman mastic") in India—and sometimes appear in the European markets as "E. Indian" or "Bombay" mastic.

The Arab tribes of N. Africa collect the resin of *P. atlantica* (see Turpentine—Chian, p. 1687), and use it as mastic.

The term "Cape mastic" has been applied to the resinous exudation of the resin-bush or *harpuis-bosch* (*Euryops multifidus*), growing plentifully at the Cape, notably in the Clanwilliam district, and utilized by the colonists.

The product exported from Manilla as "gum mastic" is probably dammar (see p. 1644).

Mezquite, Mesquit, or Mosqueit.—The mezquite tree (*Prosopis glandulosa*) is a native of the W. States of America, ranging from the Canada river southwards into Mexico, appearing in Texas, not far from the coast, and constituting the most abundant tree as far west as Colorado and the Gulf of California. It frequents dry and elevated situations where scarcely anything else will grow. Other species are named *P. dulcis* and *P. juliflora.* From natural fissures in the bark of the stem and branches, there spontaneously exudes a gum which can hardly be distinguished from *Acacia* gums (see Arabic, pp. 1630–3, especially Senegal), and is quite suitable for replacing them. As it exudes, it concretes into tears and lumps of various sizes, ranging in colour from pale-yellow to dark-amber. It is very brittle and pulverulent, and has a brilliant fracture. The quantity yielded by one tree is 1 oz.–3 lb., the best being from the branches; it might probably be much increased by judicious incising. As much as 12,000 lb. of the gum has been gathered in one year in Bexar county, Texas, and a like quantity between that and the coast. It is sent to San Francisco from the Mexican ports of the Pacific, and has recently been exported. The commercial value of the finest Mexican gum is about 1*s.* a lb.

Mochurrus, Mucherus, Mojrus, or Mochras.—This is an astringent, gummy exudation, forming irregular, inflated, hollow, dark-brown excrescences on the *Salmalia malabarica*, and apparently a result of a diseased action, whose origin has not yet been investigated. It is used medicinally by the natives of S. and W. India, mainly for its astringent qualities.

Moringa.—Moringa gum is afforded by *Moringa pterygosperma* (see Ben-oil, pp. 1378–9), and has sometimes been confounded with mochurrus. The samples vary in colour from red and pink to almost white; and in shape, from stalactitic pieces to tears. It is insoluble in water. It is obtained in great quantity, and has been proposed as a substitute for tragacanth, but its colour would probably be an obstacle. About 8·3 per cent. of the natural gum is soluble in alcohol, and 7·85 of the remainder in ether, while the residue is almost completely dissolved by alkalies.

Myrrh (Fr., *Myrrhe*; Ger., *Myrrhe*).—The sources of myrrh have been a puzzle to generations of pharmacologists, and though the recent labours of Wykeham Perry, Capt. Hunter, and Dr. Trimen have helped to remove some of the doubt surrounding the subject, there is still abundant scope for further research. That myrrh is afforded by one or more species of *Balsamodendron* seems certain. The greater part, the myrrh proper ("African" or "Turkey" myrrh), called *môr* by the Arabs, *mulmul* by the Somal, and *hira-bôl* in India, is ascribed to *B. Myrrha*, the *didthin* of the Somal, which Trimen thinks may prove to be identical with the Indian *B. Berryi.* But there is a second kind of myrrh, holding an intermediate position between true myrrh and the bdelliums, once known as "E. Indian myrrh," the *bissa-bôl* of Indian commerce, and *habaghadi* of the Somal and Arabs; this has been referred by Holmes to *B. Kafal.* A third variety of myrrh, called "Arabian" by Hanbury, is obtained in the country lying E. of Aden, from a plant which differs considerably from *B. Myrrha*, and which the Kew authorities are inclined to consider as *B. Opobalsamum*, and identical with Berg's *B. Ehrenbergianum.*

The geographical distribution of myrrh-yielding plants is, of course, similarly indefinite. Four distinct districts may be named as the probable sources:—(1) Somali-land, extending southwards from Cape Gardafui and Berbera; (2) the triangle included between Tajura, Harrar, and Shoa; (3) the neighbourhood of Ghizan, on the Arabian shore of the Red Sea, opposite Masowa; (4) the Arabian coast country stretching E. of Aden. The variety of the gum-resin yielded by each locality is not a matter of certainty. It is generally supposed, however, that true myrrh (*hira-bôl*) is obtained from the first-named district, and brought from the Wady Nogal, Mareyan, Ogadain, and Agahora, many trees being found also on the hot sunny declivities of the coast range called Ahl or Serrat mountains, at 1500–3000 ft., and a few on the hills behind Bunder Mareyeh. The *bissa-bôl* variety would seem to be chiefly the product of Harrar and the country lying W. of it, notably the district S.-W. of Zeila, the Adal desert, and the jungle of the Hawash. The Ghizan plant has been called *B. Ehrenbergianum*, and identified by Oliver with *B. Opobalsamum*, a myrrh-yielding plant found by Schweinfurth on the Bisharrin mountains of Abyssinia, but Schweinfurth does not admit the identity. The "Arabian" myrrh is produced in the Fadthli country, some 40–60 miles E. of Aden. The article locally known as *hotai* or *hodthai*, derived from *B. Playfairii*, is a bdellium rather than a myrrh, and has been described under the former name (see p. 1637). It must be admitted that future research may prove the varieties of myrrh to be due to differences in soil, climate, and time and mode of collection, as much as to specific dissimilarity in the plants themselves.

The secretion of the gum-resin, according to Marchand's examination of *B. Myrrha*, is mainly in the cortical layers, with a little in the medulla. Exudation takes place spontaneously, incisions never being made in the plants, though bruising with stones is sometimes resorted to, according to Johnston. It escapes from the bark after the manner of cherry-gum, having at first an oily and then a buttery consistence, and changing its colour while hardening from yellowish-white to golden and finally reddish. It is brought into commerce chiefly by way of Berbera, an E. African port nearly opposite Aden, where it is bought by Banian traders at the great annual fair in November–January, and shipped largely to Bombay. The crude article thus exported, having been collected by ignorant and careless natives, contains all qualities of myrrh, mixed with bdelliums and other foreign resins and gums, and various impurities such as bark and stones. At Bombay, a certain amount of sorting is done, the best samples coming to Europe, the commoner going to China for burning as incense; this sorting is carelessly performed, and needs to be supplemented by a second one here. The article is first sifted to remove the small fragments, and is then hand-picked, yet the greatest care cannot prevent the occasional presence of spurious gums, even in the best grade.

Myrrh may be distinguished from its impurities by its fracture, odour, and flavour. Commercial myrrh (*hira-bôl*) may be conveniently divided into "soft" and "dry," though brokers do not recognize any such distinction. The soft kind occurs in irregularly roundish masses, varying in size from small grains to pieces as large as hens' eggs; it has a dull, waxy fracture, and is readily impressed by the finger-nail, emitting an oily exudation. The fracture often shows whitish markings, either in narrow curves concentric to the side which was attached to the tree, or broad streaks, but never exhibiting cracks filled with transparent resin, characteristic of *bissa-bôl*. The fragrant odour of myrrh is quite *sui generis*; the flavour is similar, aromatic and slightly bitter; the colour varies from deep reddish-brown to almost colourless, the palest being most esteemed. Tiny transparent tears sometimes appear on the usually powdery surface; they are due to the resinification of oil which has been exuded. Soft myrrh, beaten in a mortar for some time, forms a greasy paste, and cannot be powdered. Dry myrrh exists in irregular lumps; its fracture is conchoidal and shiny, resisting the finger-nail, and giving no oily exudation; in odour and flavour, it agrees precisely with soft myrrh; the white markings of the latter are absent. It contains a much larger proportion of gum (75 per cent.). It is possible that the same tree may afford both soft and dry myrrh at different seasons. Parker has shown that the one is not converted into the other by long exposure to the air. In external appearance, *bissa-bôl* is much like soft myrrh; the fracture is waxy, yielding to the finger-nail, and exuding an oily matter; but the whitish markings are traversed by angular interstices filled with transparent reddish-brown resin or gum-resin; and its powerful aromatic odour is quite unlike that of true myrrh, and has been compared with the odour of apples and of "lemon-lollipop," and with the flavour of the spring mushroom. It is possible that this is the *addi* or "false myrrh" of a recent traveller in Somali Land (Georges Révoil), which he describes as being of the same colour, but more powerful odour, and easy of recognition from its always appearing oily. The main constituents of myrrh are some 40–75 per cent. of gum, 23–45 per cent. of resin, and a very uncertain quantity of essential oil. The gum is soluble in water; the resin partially in alkalies and carbon bisulphide, completely in chloroform and alcohol. The gum separated in making tincture may be used for making a common mucilage.

The principal exports of myrrh take place, as before stated, from Berbera; but several other ports participate in a minor degree. The drug is shipped from all parts of the Somali Coast to Mokha, Jedda, Aden, Makulla, the Persian Gulf, India, and China. Georges Révoil mentions 3 ports on the Medjourtine coast as receiving it for shipment:—Bender Gâsem, 30 *bohars* (of say 300 lb.) annually; Borah, 3 *bohars* annually; and Haffoûn, 25 *bohars* in 1877. This is mainly *bissa-bôl*, of which, Bombay, in 1872–3, received 224 cwt. from Aden, and shipped 138 cwt. to China. Some also finds its way overland to Brava (about 1° N. lat.) and Zanzibar. Aden exported 1439 cwt. of myrrh in 1875–6, about ½ going to Bombay, and ⅓ coming direct to the United Kingdom. The Bombay imports of *hira-bôl* in 1872–3 were:—16 cwt. from the African coast, 188 from the Red Sea, and 290 from Aden; the exports were 546 cwt., 493 being to the United Kingdom. Shanghai imported 331½ *piculs* (of 133⅓ lb.) of myrrh from Hong Kong in 1879. The approximate London market value of myrrh is 140–240*s.* a cwt. for good to fine, and 60–190*s.* for ordinary to fair. It is used largely in medicine, though possessed of no important powers; and in perfumery. In India, *bissa-bôl* is given to milch-cows and buffaloes to improve the milk-yield, and is used as a size and in incense.

Other *Balsamodendron* products are described under Balm of Gilead and Bdellium, pp. 1636–7.

Nagdana or Loban.—The resin bearing these names is produced by an undetermined species of Burseraceous tree in India. It has a deep transparent red colour, and exudes very freely during the hot months (March–April), much finding its way into the earth, and there concreting, to be dug up long after the tree has disappeared. Large masses are sometimes found after a forest fire.

Olibanum (FR., *Encens*; GER., *Weihrauch*).—The ignorance concerning the origin of myrrh is equally prevalent in the case of olibanum. The results of the very attentive study which Capt. Hunter has long devoted to the subject may be summarized as follows. There appear to be five different kinds or grades, two of which bear dissimilar names in E. and W. Somali Land. The names given are:—(1) *Mohr ad* or *mohr lafôd*, (2) *mohr madao*, (3) *mohr dadbêd* or *mohr as*, (4) *karâon*, (5) *yegaar*. (1) The first is obtained in strips sometimes 1 ft. long, though the *ad* is never so long as the *lafôd*; the plants yielding it are found on the coast range, especially near water-courses. The Kew authorities consider the *lafôd* plant to be probably a smooth-leaved form of *Boswellia Carterii*, while the *ad* plant is identified with *B. Bhau-Dajiana*, which may be itself an extreme form of *B. Carterii*. (2) The *madao* tree is comparatively rare, and its product is not highly esteemed, as it is sticky, and apt to discolour and depreciate other kinds when mixed with them. (3) *Dadbêd* and *as* are reddish-coloured, and afforded by a tree which is "common near the sea," but quite unknown to botany. (4) The *karâon* kind is but little valued, and is only added to the others as a make-weight; the tree is alleged to be rare, growing isolated on hill-tops. Nothing is known of it scientifically. (5) The produce of the *yegaar* or *gekar* plant (*Boswellia Frereana*) is kept quite distinct from the four preceding kinds (which are indiscriminately mixed), and is known as *mati* or *luban-mati* (variously spelt); it is likened by Capt. Hunter to the product of a Socotran tree called *amîru*, which is likewise unknown.

The region occupied by the trees yielding olibanum or true frankincense is defined by Carter as extending over that portion of Somali Land contained between the Sabhan mountains (in 17° 30′ N. lat., and 55° 23′ E. long.) and the town of Damkote, in the Bay of Al Kammar (in 52° 47′ E. long.). S. Arabia is said no longer to produce any. The plants affect two distinct localities: the Nedjee, or high land, 2 days' journey from the sea; and the Sahil, or plain on the coast. Capt. Kempthorne describes the trees on the coast of Adel as growing without soil, out of polished marble rocks, to which they are attached by a thick mass of the weathered rock, the growth of the trees appearing to be finer in proportion to the purity of the marble. The young trees are said to furnish the most valuable gum-resin, the older yielding a clear glutinous fluid resembling copal varnish. The fragrant gum-resin is distributed throughout the bark, leaves, and flowers of the plants. Its collection by the Medjourtine [Mijjertheyn] tribe of the Somalis is conducted as follows:—During the hot season, commencing about the end of February or beginning of March, the trees are visited in succession, and a deep incision is made in the stem of each, a narrow strip of bark being torn off for about 5 in. below the wound. After about a month, the old incision is deepened; and after the 3rd month, this is repeated. When the exudation is supposed to have attained the proper consistence, parties of men and boys go out and scrape the large globules into baskets, making a separate collection of the inferior quality which has run down the stems. As first removed from the trees, the gum-resin is very soft, but it soon hardens. The collecting is repeated every fortnight during the season, the crop increasing as it advances, till mid-September, when the first rain closes the year's harvest, and spoils a portion of the product. The collection of the gum-resin in S. Arabia, is (or rather was, for it is said to be now discontinued) performed by bands of Somalis from the opposite coast. Longitudinal incisions are made in the bark in May and December, when it appears much distended. The gum-resin issues as a milky fluid, and partly concretes on the stems beneath the incisions, partly falls on the ground. The Arabian article was always considered inferior to the African. The present supplies bearing Arabic names are said to be imported from Africa into the Arabian ports whence they are named.

Commercial olibanum fluctuates in quality and appearance. Speaking generally, it is a dry gum-resin consisting of long detached tears mingled with irregular lumps, and often with fragments of brown papery bark adhering. The colour is pale-yellow or brownish to greenish or nearly colourless. The smallest grains even are not transparent, but become so (or nearly so) by heating at 94° (201¼° F.). The fracture is dull and waxy, with no trace of crystallization. The gum-resin softens in the mouth, giving a turpentinous and slightly bitter flavour; the odour is agreeably aromatic, and much intensified by a high temperature. The composition may be generally stated as 4–7 per cent. of essential oil, 27–35 of gum, and the remainder of resin. The local classification and valuation of olibanum may be approximately given as follows:—(1) *Fessous* [*fasus*], a dry pure article, consisting of tears of powerful odour, exported from Ongar, and estimated at 30 dollars (of 2*s.* 11*d.*) per *bohar* (of variously 300, 440, and 450 lb.); (2) *naghua*, less pure, 20 dol.; (3) *wodjendel* [*madjendel*, *jandul*], very impure, containing much bark, 15 dol.; (4) *liban maheri* [*mascati*], quite white, a very rare article, 42 dol. The London market values are about the following:—Pale drop, 60–90*s.* a cwt.; amber and yellow, 40–85*s.*; garblings and siftings, 15–35*s.* The one important use of the gum-resin is for burning as incense.

Olibanum is shipped from most of the ports of the Somali country, but chiefly from Berbera, Bunder Mareyeh, and Zeila. The shipments from the Arabian coast between Damkote and Al Kammar are now unimportant, and said to be merely re-exports (received from African ports). The chief destinations of the gum-resin are Bombay and Aden, though Jedda is reported to receive some 12,000*l.* worth annually by way of the Straits of Bab-el-Mandeb. In 1872-3, Bombay imported 18,751 cwt., and re-exported 24,461 cwt., of which, 17,446 went to the United Kingdom, and 6184 to China. The Chinese imports in 1879 were 1124 *piculs* (of 133⅓ lb.) at Shanghai [they were 1360 in 1872], and 642 at Hankow.

There are other resin-yielding species of *Boswellia*, as follows:—(1) *B. papyrifera* [*Plösslea floribunda*], the *makar* of Sennaar and the mountainous region up to an altitude of 4000 ft. on the Takazze and Mareb rivers (Abyssinia), affords a transparent resin, which is not collected, and has no apparent value. (2) *B. glabra* and *serrata*, especially abundant on the trap hills of the Deccan and Satpura range, and readily propagated by cuttings, yield a soft, fragrant resin, which is locally used as incense, and called " Indian olibanum," or *dup salai*. 3. *B. Frereana*, a tree growing on the bare limestone hills near Bunder Mareyeh, an important village lying over 30 miles W. of Cape Gardafui. The trees are carefully guarded, and sometimes propagated. The resin, the " Oriental " or " African " elemi of older writers, and one of the resins anciently called " animi," exudes abundantly after incisions (which are made every week during the season), and is collected by the Somalis, and disposed of to traders for conveyance to Jedda and the Yemen ports. It occurs in detached tears, and in stalactitic masses of several oz., the tears being more esteemed by the natives. It has a brilliant conchoidal fracture, an agreeable odour of lemon and turpentine, an external, thin, white crust, and generally fragments of the papery bark of the tree adhering. It differs essentially in appearance from the other kinds of olibanum. It is largely used by the orientals as a masticatory and for incense, and arrives rarely in Europe with olibanum. Aden received 1928 cwt. in 1875–6, of which, ½ went to Egypt and Trieste, ¼ to Red Sea ports, ⅛ to the United Kingdom, and the rest to Bombay and the Danakil (Dankali) coast. Prof. Flückiger thinks it well fitted for any purpose to which common rosin, Burgundy pitch, and the allied resins or turpentines are applied.

Opopanax.—This gum-resin is attributed to *Opopanax Chironium*, a parsnip-like plant of S. Europe; the allied product of *O. persicum* obtained from Persia differs in appearance and odour, though the drug met with in Indian bazars is regarded as of Persian origin. It is now extinct in European medicine, and rarely met with, though apparently retaining considerable importance in native Indian and Chinese practice. The roots are taken up when the plant begins to sprout, and are broken off, the escaping juice being caught in leaves placed beneath, where it concretes in hard, nodular, earthy-looking, bright orange-brown lumps, of penetrating offensive odour. It consists mainly of about 42 per cent. of resin and 33 of gum. It is fusible at 50° (122° F.), and partially soluble in alkalies, alcohol, and ether.

Orange.—It is recorded that the stems of the members of the *Citrus* family afford a useful gum, said to be collected in the W. Indies; but such a product is unknown in commerce.

Peru Balsam.—(Fr., *Baume de Pérou, de San Salvador*; Ger., *Perubalsam*).—This misnamed gum-resin, the *balsamo negro* of the American Spaniards, and *hoo-sheet* of the native Indians, is produced almost (if not quite) exclusively by *Myroxylon* [*Myrospermum*] *Pereiræ*, a native of the so-called Balsam Coast, comprising the Indian Reservation Lands, forming a small district in the State of San Salvador, lying between 13° 35′ and 14° 10′ N. lat., and 89° and 89° 40′ W. long. Its only connection with Peru is the fact of its having been shipped viâ Callao to Europe in the early days of the trade. The trees grow in dense forests, and are often enclosed or marked by their owners, being valuable property. The principal Indian *pueblos* around which the balsam is produced are enumerated by Dr. Dorat (in 1863) as follows:—(1) Juisnagua, about 400 trees; (2) Tepocoyo, annual produce about 6 *arrobas* (of 25 lb.); (3) Tamanique, 1400 trees, giving some 160 *arrobas* yearly; (4) Chiltinapan, 2500 trees, affording 450 *arrobas* per annum; (5) Talnique, not more than 500 trees; (6) Jicalapa, about 1200 trees under cultivation, but many more in the uncleared woods; (7) Teotepeque, plenty of trees on the mountain slopes, but only 300 worked; (8) Comasagua, 1000 trees, but their cultivation giving way to coffee; (9) Jayaque, about 1000 trees under cultivation.

Concerning the secretion of the balsam, next to nothing is known. Early accounts speak of a superior article obtained by making incisions in the bark and probably reaching into the wood, but the present method of gathering the balsam is universally as follows:—After the last rains, in November–December, the trunks of the trees are beaten with some blunt instrument in four equidistant patches until the bark is loosened, a similar number of intermediate patches being left unbruised for the following year. The injured bark splits up, and may be easily detached; it already exhibits a slight exudation of fragrant balsam, but not sufficient to repay collection. To promote the flow, the bruised bark is charred some 5–6 days later by the application of bundles of burning wood, and after about another week, the charred bark either falls or is torn off, and the exudation begins in earnest. The wounds are then staunched by means of rags or cotton-wool, which absorbs the balsam; these, after a few days saturation, are collected and boiled in water. The greater part of the balsam is thus freed from them, and collects beneath the water, but the rags also undergo a rude wringing in a kind of rope bag, by which some further balsam is recovered from them, and added to the first. The contents of the boiler cool during the night, and next day the water is decanted, and the balsam is put up in *tecomates* (gourds) or other vessels for the market. The balsam thus prepared is locally known as *de trapo*. A small quantity of inferior grade is produced, according to Wyss, by boiling the bark in water; this is termed *de cascaro* or *tacuasonte*. The operation of collecting continues till May; it is suspended during the rains, but carried on more or less in the dog-days (15 July–15 August). The beating and staunching are only performed on four days of each week, giving 4 *cosechas* (harvests) a month. In the 2nd year, recourse is had to the patches left untouched from the first year. The bark renews itself in about two years, and it is thus possible to obtain an annual yield of about 2 lb. from the same tree for some 30 years, after which, if allowed 5–6 years' respite, it will again produce.

The balsam is a treacly liquid, of black colour in bulk, but deep orange-brown and transparent in a thin layer; its odour is balsamic and smoky, but fragrant and pleasant when developed by warming. Its sp. gr. is 1·15–1·16. Years of exposure to the air do not effect any change in it. It is only very slightly soluble in water, dilute alcohol, benzol, ether, and essential and fatty oils, and not at all in petroleum-spirit, but mixes readily with absolute alcohol, glacial acetic acid, acetone, and chloroform. The balsam contains about 32–38 per cent. of resin, the remainder being almost entirely cinnameine ($C_{16}H_{14}O_2$). An adulterated article is said to be largely prepared in Bremen. The balsam is mostly shipped at Acajutla, in San Salvador, about 40 miles from the Guatemalan frontier. The export in 1855 was stated at 22,804 lb., value 19,827 dollars (of 4*s.*); in 1876, the value was given as 78,189 dol. The London market value of the drug is about 7*s.* 6*d.* a lb. Its chief use is medicinal (see Drugs, p. 819); it is also employed in scenting soap.

The tree has been introduced into Ceylon, where it flourishes luxuriantly, but the balsam does not seem to have yet come into commerce from that island.

Besides tolu, which is the subject of a separate article (see p. 1684), there are several allied balsamic products demanding some notice. (1) The first that may be mentioned is the so-called "white" or "virgin" balsam, the *balsamo blanco* or *catolico*, or *balsamito*, a soft resin secreted in the large ducts of the fruit of the species just described, and extracted by expression. It is highly valued and scarce, and never sent into the market. (2) Much more important commercially is the fragrant balsamic resin collected from *Myroxylon peruiferum*, a large tree found in Tropical America, from S. Mexico to Peru, and even as far south as the Brazilian province of Rio Janeiro. It prefers moist mountain-valleys, up to 600 feet. The balsam extracted from the wood might, in the opinion of Theodor Peckolt, be conveniently substituted for the officinal balsam, especially as it mixes readily with castor-oil in all proportions. The exudation can be absorbed by cotton-wool, much in the same way as Peru balsam. In the fruit-pods, surrounding the seed, is found a small quantity of pale-yellowish aromatic oleo-resin, which is carefully preserved and highly prized under the name of *anguay do guaiani* or *balsamo do espirito santo*; it rarely enters commerce. (3) A balsam is obtained from incisions in the stem of the *oleo pardo* or *cabure-iba* (*Myrocarpus fastigiatus*).

Phormium.—Almost every portion of the plant *Phormium tenax* (see Fibrous Substances pp. 986–93), but especially the bases of the leaves, is replete with a gum which gives great trouble in the processes for extracting the fibre of the plant. The utilization of the gum deserves more attention than it has yet received, as it forms a mucilage capable of replacing that of gum arabic for most purposes.

Piney.—The copalline resins known as "white dammar," "piney resin," or "piney varnish" of S. India and Ceylon, and by some authors (e. g. Wiesner) termed "Manilla copal," are produced by two species of *Vateria: V. indica* of the W. Peninsula, from Canara to Travancore; and *V. acuminata*, common in the hotter part of Ceylon up to 2000 ft. The resin is obtained either by making incisions in the bark of the trees, and allowing it to exude and concrete; or by making excavations into the tree, where the liquid resin may collect. Sometimes masses of the hardened resin are found on splitting open old trees. When recently exuded, the resin is quite soft (then termed "varnish"), but it soon hardens into a brittle mass, varying in colour from bright-green to deep-amber, usually translucent, sometimes containing many air-bubbles. It is more soluble in alcohol than black dammar (see p. 1644); it dissolves readily in chloroform, and might serve the purposes of photographers' varnish; it has an advantage over copal in being quite soluble in turpentine and drying oils without preliminary fusion; its solution in turpentine is turbid, but the addition of powdered charcoal, and subsequent filtering, renders it transparent and colourless, and the solution mixes readily with the drying oils. The sp. gr. of the resin is about 1·121.

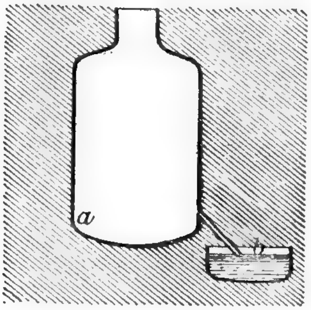
Somewhat similar products are said to be afforded by *Vatica* [*Vateria*, *Retinodendron*, *Seidlia*] *lanceæfolia* of E. Bengal, Silhet, Khasia, Assam, and Bhotan, and by *V. Roxburghiana* in S. Canara, Travancore, and Ceylon.

Other copals are described under Copal and Animi (pp. 1640–4), Dammar (pp. 1644–5), Jutahyseca (p. 1666), and Kauri (pp. 1666–7).

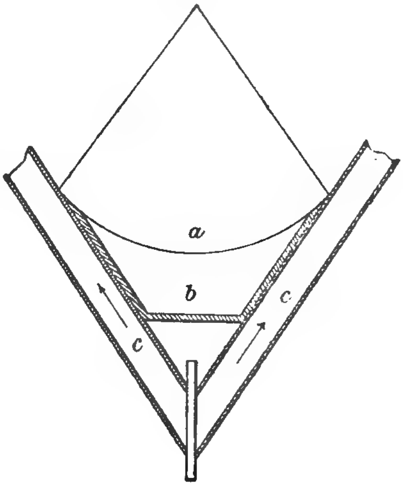
Pitches (Fr., *Poix*; Ger., *Pech*).—The term "pitch" embraces two products, "common" or "black," and "white" or "Burgundy." Mineral pitch, bitumen, or asphalt, has been described under the last name (see pp. 341–6).

1. *Common or Black Pitch* (Fr., *Poix noire*; Ger., *Schiffspech, Schusterpech, Schwarzes Pech*).—This article is produced by a further distillation of the tar obtained in the dry distillation of pine-wood (see p. 1683), and from the residues left in the boiler after the distillation of the crude turpentine to separate the rosin and spirit. The latter are heated in the open air, and filtered through straw mats, to afford a little more turpentine. These mats, charged with impurities and containing still a certain quantity of turpentine, were placed, according to the old plan, in a brick furnace (Fig. 1180); fire is kindled at the top, and the resinous matters escape by a pipe into the cooler *b*, a passage existing at *a* for the removal of the ashes. In works having the modern improvements, there only remains in the boiler (*b*, Fig. 1184) the residues which will not pass through the filter *d*, and the heavy matters settled below this orifice. These residues are filtered through mats, as by the old system, and afford a little turpentine. The mats are then placed in the apparatus shown in Fig. 1181, consisting of a double-lined trough, with steam circulating in the intermediate space *c*. The residues are placed on the metallic gauze tray *a*, and the box is covered to prevent evaporation of the spirit. Under the influence of the heat, the turpentine falls into the space *b*. It is then distilled in the apparatus shown in Fig. 1185, affording pitch, and a little spirit. The straw mats may finally be ignited in the brick chamber shown in Fig. 1180, thus producing a small quantity of tar, but they are more generally utilized as fuel.

1180.



1181.



Pitch is chiefly manufactured in countries which afford tar (see p. 1683), but also on a smaller scale in England. It is an opaque black substance, with shining conchoidal fracture, peculiar unpleasant odour, scarcely perceptible flavour, dissolving in the same menstrua as tar, and capable of being kneaded when softened by the heat of the hand. It is largely used in ointments, though probably devoid of medicinal properties. Its approximate London market value is 5–6*s.* a cwt. for British, and 7*s.* 6*d.* for Archangel. Our imports in 1880 were 63,430 cwt., value 16,687*l.*; our exports in the same year were 9967 cwt., 3420*l.* We imported 35,606 cwt. in 1876, and 81,558 in 1877. The imports for 1880 were contributed as follows:—Russia, 35,770 cwt, 9849*l.*; British W. Indies, 15,476 cwt., 1990*l.*; other countries, 12,184 cwt., 4848*l.* It is obvious that the W. Indian article is not pitch at all, but asphalt (see pp. 341–6), from the so-called Pitch Lake of Trinidad, and perhaps from Dominica as well. Our imports from Russia rose from 30,124 cwt. in 1876, to 47,269 in 1877. The total exports from Archangel were 15,209 barrels in 1874, 19,168 in 1875, 17,640 in 1876, 23,988 in 1877, 16,759 in 1878; the proportions taken by the several countries in 1878 were 9130 barrels by Great Britain, 1630 by Holland, 490 by France, 4175 by Italy, 1319 by Germany, and 15 by Norway. Boston (U.S.), in 1880, received 1848 barrels of pitch, and exported 3199. Wilmington (N. Carolina), in 1878, exported 4724 barrels, 331 going abroad; the aggregate value was 1600*l.* New York exported 5520 barrels in 1879. Hamburg, in 1881, imported 3492 tons, of which, 1346 came from Finland, and 2056 from Archangel. The Finnish port of Wiborg exported 207 barrels of pitch and tar, value 2900 Finnish marks (of 9½*d.*) to Norway, Germany, and England.

Burgundy Pitch (Fr., *Poix jaune, de Bourgogne, des Vosges*; Ger., *Fichtenharz, Tannenharz*).—This is a product of *Pinus Abies* [*Abies excelsa*], the spruce fir of Norway (see Timber—White Deal). It is prepared in Finland, the Black Forest, Baden, Austria, and the Bernese Jura (where it is called *poix blanche*). It is obtained from the trees by making perpendicular incisions in the stems about 1½ in. wide and deep; the exuding resin is scraped off by an iron instrument, and purified. This wounding of the trees causes so much injury to the timber that the collection of the resin is prohibited in the Government forests of Baden and Würtemberg. The purification is effected by melting the pitch either in contact with steam, or in hot water, and straining. In the latter case, the product (called *Wasserharz*) is opaque and highly charged with water, and needs to be improved by further straining and evaporation of the moisture. The production is not very great. Baron Linder's estate near Helsingfors (Finland) gave 689 cwt. in 1867, and an estate at Ihn, 1575 cwt. The Swiss forests yield about 900 *quintals* (of 220½ lb.) yearly. The pure pitch is opaque, yellowish-brown, hard, brittle, strongly adhesive, with a conchoidal fracture, and agreeable aromatic odour, It is employed in plaisters in this country; in Germany, mixed with colophony or thus, it forms the composition termed *Brauerpech*, used for lining beer-barrels.

The true pitch is very extensively replaced by an artificial compound, termed *poix blanche* in Belgium, and *poix blanche factice* in France. It is composed either of galipot melted in water, stirred, and filtered hot, or of a mixture of galipot (thus) or colophony with turpentine, turpentine-oil, or Bordeaux turpentine, coloured with palm-oil. The artificial article differs from the genuine in being completely soluble in alcohol, less tenacious and adherent, and of stronger and less fragrant odour.

Quebracho.—The so-called "gum" of *Quebracho colorado* is in reality an astringent extract, and will be described under Tannin.

Retinite.—This name was applied some years since to a species of fossil resin, found in small nodules and masses, sometimes in imperfect veins, in the brown coal and gold diggings at Caversham, Tarapeton, Waitahuna, and other parts of Otago (New Zealand); also in Borneo. It melts without decomposition, emitting an aromatic odour, and burns with a smoky flame; warmed gently with alcohol, it softens, and becomes very tenacious and adhesive. The sp. gr. is about 1·049. The colour varies from pale-yellow to dark-brown.

Rimu.—The *rimu* or *Dacrydium cupressinum* of New Zealand yields an exudation which can be converted into a varnish in no way inferior to copal.

Rosin or Colophony (Fr., *Colophane*, *Brai*, *Arcanson*; Ger., *Colophonium*, *Geigenharz*, *Gemeines Harz*) **and Rosin-oil.**—The several kinds of rosin, colophony, or resin proper are the solid residues obtained by the distillation of the turpentines (see pp. 1686–92). The crude turpentine or oleo-resin is submitted to aqueous distillation in a copper vessel, in place of the old-fashioned iron still which produced a red-coloured oil. The still, having a capacity of some 15 barrels (of 220 lb. each), is charged with crude oleo-resin in the early morning; heat is applied either by an ordinary furnace, or by a steam-jacket, until the mass attains a uniform temperature of 100°–158° (212°–316° F.). This is continued until the accidental water contained in the crude oleo-resin has been driven off, together with pyroligneous and formic acids, ether, and methylic alcohol, the whole being known as "low wine." This accomplished, a small stream of cold water is admitted, so that the heat is kept at or below 158° (316° F.), the boiling-point of turpentine-oil. The distillation continues, a mixture of water and turpentine-oil passing over into a wooden separating-tub; this is merely a tub with two outlet taps, one near the bottom, the other about half-way from the top, the difference in sp. gr. of the two bodies permitting their withdrawal into separate receptacles. The progress of the distillation is judged by means of samples taken at intervals in a graduated measure; when the liquid shows 9 parts of water to 1 of turpentine-oil, the distillation is stopped, the still-cap is removed, and the hot rosin remaining in a fluid condition in the still is drawn off by a tap near the bottom, and passed through a fine strainer into a vat, whence it is baled by long-handled wooden buckets into barrels for sale.

The grade of the rosin depends (1) upon the quality of the crude oleo-resin under treatment, and (2) upon the skill with which the operation is conducted. The so-called "virgin turpentine," the first exudation from a newly-chipped tree, will give "window-glass" rosin of varying quality; "yellow dip," the runnings of the second and subsequent years, affords medium grades of rosin; while "scrapings," the inspissated gum from the tree facings (see Thus, p. 1684), yields an inferior dark rosin. Black rosin is not caused by burning in the still, as has been stated. Opacity is due to the presence of water, by which, crystals of abietic acid are formed. Every turpentine produces its own peculiar rosin. That most common in continental Europe is obtained from Bordeaux turpentine (see p. 1687); in England and America, that derived from the latter country holds the foremost place. Speaking in general terms, rosin is an almost flavourless body, of faint but characteristic odour, and varying in colour from the palest amber to the deepest black, and from translucent to opaque. Common yellow rosin is homogeneous, amorphous, very friable, and of sp. gr. 1·07; it softens at 80° (176° F.), and fuses completely to a limpid yellow liquid at 100° (212° F.). It is insoluble in water, but soluble in acetone and benzol in nearly all proportions, in 8 parts of alcohol of 88° at 15°–20° (59°–68° F.), and pretty freely in ether and fatty oils. Treated with boiling alkaline solutions, it takes up the elements of water to form abietic acid, which then unites with the alkali present to form rosin-soap (see Soap). The rosin of Venice turpentine (see p. 1691) dissolves in 2 parts of hot alcohol of 75°. That of Canadian turpentine (see p. 1686) consists of two ingredients, one (78·7 per cent.) soluble in boiling absolute alcohol and glacial acetic acid, and the other (21·3 per cent.) soluble in ether; both the turpentine and the rosin are insoluble in caustic alkalies. The rosin of Strassburg turpentine (see p. 1691) is completely soluble in glacial acetic acid, but incompletely in acetone and absolute alcohol. Medicinally, rosin is employed in plaisters; industrially, in the manufacture of rosin-soap, sealing-wax, varnishes, and cements, and for soldering metals. The approximate London market value is 5–15*s.* a cwt.

The commerce in rosin is considerable. Our imports in 1880 were 1,051,825 cwt., value 323,319*l.*, from the United States, and 31,577 cwt., 13,468*l.*, from other countries; total, 1,083,402 cwt., 336,787*l.* Our exports in the same year were 31,491 cwt., 10,593*l.* The imports from America have not fluctuated much during late years, having been 966,109 cwt. in 1876, and 1,105,367 in 1879. The imports from France were 13,851 cwt. in 1876, 6389 in 1877, 37,840 in 1879, and 29,278 in 1880. Recent details of American shipments are as follows:—New York: 157,834 barrels (of 220 lb.) in 1879; 234,778 in 1878, being 51,753 to Great Britain, 5166 to France, 101,009 to N. Europe, 16,019 to other Europe, 60,831 to S. America, E. and W. Indies, &c. Mobile: in 1878, exports abroad, 49,247 bar., 17,448*l.*; sent inland and coastwise, 67,630 bar., 23,604*l.*; in 1880, exports, 18,795 bar., 9582*l.*; inland and coastwise, 27,140 bar., 14,019*l.* Savannah: exports, 85,551 bar. (42,443 being to English ports) in 1879; in 1880, exports, 77,339 bar., 57,478*l.*, and coastwise, 141,435 bar. Boston: in 1878, received 17,556 bar., exported 4032; in 1880, received 22,732 bar., exported 5038. New Orleans: exports, 1880, 821 bar. Philadelphia: exports, 1879, 3310 bar. Baltimore: exports, 6735 bar. in 1877, 3120 in 1879, 13,031 in 1880. Wilmington (N. Carolina): in 1878, 516,279 bar. exported, and 65,679 coastwise; total value, 162,518*l.* The Italian port of Venice despatched 557 tons, value 4462*l.*, in 1878, and 560 tons, 4487*l.*, in 1879. Of Chinese ports, Hankow shipped 2055½ *piculs* (of 133⅓ lb.) in 1878 and Wenchow, 25 *piculs* in the same year.

The preparation of rosin for soap-making purposes is described under Soap.

Rosin-oil.—This product, to which frequent allusion is made in the article on Oils and Fatty Substances, notably in the section relating to Detection and Analysis (see pp. 1467–9, 1476), is manufactured in the following manner. The rosin, usually of the lower grades, is introduced into an iron still, and heated up to 158°–160° (316°–320° F.). Water, pyroligneous acid, and naphtha pass over at first, and until the rosin is exhausted of naphtha. The temperature is then raised to near the red-heat of iron, when the rosin boils, and crude rosin-oil distils over. It is a heavy, nearly opaque, whitish, viscid fluid, opalescent on the surface. It is rectified by redistillation, and the resulting oil is transparent, dark-red by transmitted light, with a bluish cast by reflected light, and sometimes highly opalescent.

Sagapenum.—The origin of sagapenum is wrapped in obscurity. It is supposed to be produced by a species of *Ferula*, and *F. persica* has been especially pointed to, but nothing certain is known on the subject. The locality affording it cannot even be indicated, though there is reason to suppose that it comes from Persia and the countries to the east, the village of Māh, near Ispahan, being particularly referred to. The drug is now extremely rare, and scarcely to be had in a pure state even in Bombay; formerly it would seem to have been plentiful. It is a gum-resin, forming a tough softish mass of strongly agglutinated small tears, of brownish colour, manifesting no pink hue when broken, nor an alliaceous odour, but acquiring a most intense and permanent blue colour when immersed in cold hydrochloric acid of 1·13 sp. gr. More rarely it occurs in translucent yellowish-brown tears, varying in size from a hazel-nut to a walnut. These characteristics serve to distinguish it from ammoniacum, galbanum, and opoponax, which it otherwise resembles, and which are often substituted for it by the native druggists of India.

Sandarach (Fr., *Sandaraque*; Ger., *Sandarac*).—Sandarach when in powder is termed "pounce"; it has also been called "juniper-gum" or "-resin," from the erroneous supposition that it was afforded by *Juniperus spp.*; and the closely allied Australian product has been introduced as "pine-gum."

The tree affording sandarach is *Callitris quadrivalvis* [*Thuja articulata*, *Frenela Fontanesii*], remarkable for its wood (see Timber—Alerce); it is indigenous to the mountains of N. Africa, from the Atlantic to E. Algeria, its eastern limit being undetermined. The resin exudes naturally from the bark of the stem, but the common practice is to make incisions in the stem, particularly near the base, by which the flow is much increased. The juice rapidly hardens on exposure, and is collected by the Moors, and carried by them to Mogador for export to Europe. It occurs in commerce mostly in cylindrical tears, which are occasionally agglutinated. Its colour is pale-yellow to pale red-brown, the best being very clear and transparent. The exterior often appears "powdery," from the occurrence of innumerable fissures by unequal contraction in drying. It has about the same hardness as kauri, softens at 100° (212° F.), and melts and swells at 150° (302° F.); its sp. gr. is 1·066–1·092, the fracture is clean and shiny, and the odour is weak and aromatic, increasing with heat. It is not softened by boiling water, and is not soluble in caustic soda or acetic acid; it is partially soluble in benzol, rectified petroleum, chloroform, and turpentine-oil, very slightly in carbon bisulphide and boiling linseed-oil, but completely in alcohol and ether. Sandarach is said to be adulterated with gum arabic, but this seems doubtful; more commonly it is itself substituted for mastic, from which it may be distinguished by the softness of the latter, its complete solubility in turpentine-oil, and incomplete in cold alcohol. Formerly of wide renown in medicine, the resin is now valued, in Europe at least, principally as an ingredient of varnishes, to increase the hardness and glossiness; powdered, under the name of "pounce," it is used for preparing the surface of parchment and paper to receive writing. Its approximate price in the London drug market is 60–115*s.* a cwt.

The Australian species of *Callitris* yield a resin which can scarcely be distinguished from the African. The principal species seem to be *C. verrucosa* [*Frenela crassivalvis*], *C. cupressiformis*, and *C.* [*F.*] *robusta*. They are abundant on the sandy tracts of the Murray River (Victoria), and are scattered more or less throughout the whole continent, being recorded from King George's Sound and Shark Bay (W. Australia), and from Arnhem Land (N. Australia). The resin might easily become an article of local commerce, if not of export.

Sarcocolla.—The plant and country affording this medicinal gum-resin are unknown. It has been referred to a *Penæa sp.*, found only in the Cape, but this is obviously incorrect. Dr. Dymock believes it to be produced by one of the desert *Leguminosæ*, probably an *Astragalus*. Native evidence ascribes it to Persia and Turkistan; this is borne out by the fact that the Bombay imports of the drug, which are considerable, come entirely from Bushire, in the Persian Gulf. It arrives in bags containing about 2 cwt., always largely intermixed with remains of the plant (except leaves) and with sand, whence Dymock supposes it to be collected by beating the bushes after the leaves have fallen, and allowing it to accumulate upon the ground. It holds an important place in Indian native pharmacy.

Satin-wood.—The satin-wood tree of India and Ceylon (*Swietenia Chloroxylon*) occurs in fractured and agglutinated tears, brittle, brown, translucent, and soluble in water, giving a turbid, dark mahogany-coloured mucilage, having an odour of fusel-oil. It is not a commercial article.

Scammony.—See Drugs, pp. 823–4.

Schaufite.—This name has been applied to a fossil resin found in some abundance in schistose sandstone beds traversing the petroleum region in Bukowina, Galicia, Bohemia, and S. Austria. It forms veins of ½–4 in. in thickness. The colour is purplish to blood-red, and the hardness sufficient to admit of polishing, but not turning. It is slightly soluble in alcohol, benzine, and chloroform, entirely in sulphuric acid, and is saponifiable by caustic alkali. Distilled, it leaves a reddish-brown colophony, giving a brilliant varnish with turpentine and fatty oils.

Storax (Fr., *Styrax*; Ger., *Storax*).—Several products call for description under this head, the most important being liquid storax or liquidambar.

Liquid Storax.—This is obtained from *Liquidambar orientale* [*imberbe*], a plane-like tree forming forests in S.-W. Asia Minor, notably near Melasso, about Budrum and Monghla, near Giova and Ulla, by Marmorizza and Isgengak in the valley of the El-Azi, and possibly near Narkislik, a village near Alexandretta; but it is unknown in the islands of the Mediterranean. The resin is collected by the Yuruk nomads, by first removing the outer bark, and then scraping away the resinous inner bark, accumulating it in some quantity in pits. This bark is then either pressed dry in the first instance, or at once boiled with water in large copper vessels, whereby the resin is separated and can be skimmed off. The boiled bark is packed in hair bags and subjected to pressure while hot water is poured over. Thus a second quantity of resin is procured. The water used in the boiling is probably from the sea or saline lakes, as attested by the presence of salt in the drug. The result of the process is an opaque, grey, semi-fluid resin, of pleasant balsamic odour after long keeping, and pungent burning aromatic flavour; and cakes of fragrant brown bark, which, coarsely powdered, is mixed up with storax, honey, and other substances, into an odoriferous compound, of which there are many qualities. Some 25 years ago the production of the resin was computed at about 800 cwt. per annum. It is mostly exported in casks by way of Constantinople, Smyrna, Syra, and Alexandria; some is packed with water in goat-skins for transport to Smyrna, and sent thence in barrels to Trieste. The use of the resin in this country is trifling and wholly medicinal (see Drugs, p. 826); the chief markets for it are India and China. Scherzer (1880) states the exports from Smyrna at 25,000–30,000 *okes* (of 2·83 lb.), worth 7 *piastres* (say 1*s.* 3*d.*) the *oke*, chiefly for China and Egypt, for use in perfumery, fumigation, and church incense. It is said to have been employed in the United States as an adulterant of tolu.

True Storax.—True storax was a benzoin-like fragrant resin, afforded by the stem of *Styrax officinale*, of Greece, Asia Minor, Syria, Italy, and S. France; it has ceased to be produced since the trees have been reduced to mere bushes by cutting.

American Liquidambar.—This is derived from *Liquidambar styraciflua*, a large tree of the American continent, from Connecticut and Illinois southward to Mexico and Guatemala. In the United States, small quantities of a balsamic resin, termed "sweet gum," and sometimes used as a masticatory, are collected from natural fissures or incisions made in the tree. In Central America, the exudation is much more freely afforded, and is collected by the Indians in small cylinders, to be burnt as incense. As met with in commerce, it is a transparent, thick, fluid, golden-brown oleo-resin, of balsamic odour, and similar flavour.

E. Asian Liquidambar.—This is of two kinds. The first is a dry terebinthinous fragrant resin produced by *L. formosana* in Formosa and S. China; it is used by the Chinese. The second is a fragrant balsam obtained from *L. Altingiana* [*Altingia excelsa*], of Assam, Burma, and the E. Archipelago. It is collected in small quantity in Java from incisions in the trunk; in Burma, a pellucid light-yellowish kind is procured in the same way, besides a darker, thicker quality by boring the stem and applying fire around it.

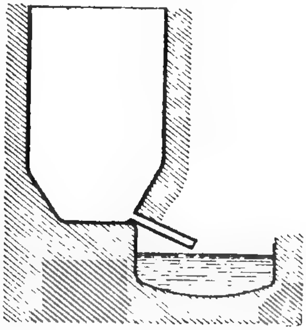
Tamanu and Tacamahaca.—The name *tamanu* is applied only to the resin of *Calophyllum inophyllum*, but *tacamahaca* (variously spelt) is used indiscriminately for the resins of *Icica Tacamahaca, Calophyllum inophyllum, Elaphrium tomentosum, Populus balsamifera*, and *Calophyllum Calaba*. In the present article, the terms will be restricted to the resins of *Calophyllum spp.*, particularly *C. inophyllum.* The geographical distribution of this tree has been given elsewhere (see Oils and Fatty Substances—Dilo, pp. 1387–8). The resin exudes both spontaneously and from incisions in the bark and roots. It is green or yellow and liquid when first it escapes, but hardens in time to a brittle aromatic mass, soluble in alcohol and ether. *C. Calaba* seems to yield a similar article in Venezuela. The Venezuelan port of Maracaibo shipped 583 lb. of tacamahaca, value 176½ dol. (of 4*s.* 2*d.*) in 1880.

Tars.—The tars here to be considered are the so-called "wood-tars," obtained by submitting the wood of the stems and roots of certain trees to a process of destructive distillation. They are of several kinds, and will be described in the following alphabetic order:—(1) Archangel or Stockholm, (2) beech, (3) birch, (4) dummele, (5) ganda, (6) juniper, (7) teak.

1. *Archangel or Stockholm Tar* (FR., *Goudron végétal, Poix liquide*; GER., *Holztheer, Fichtentheer*).—This, by far the most important of the vegetable tars, is produced in Finland, Central and N. Russia, and Sweden, chiefly from *Pinus silvestris* and *P. Ledebourii* [*Larix sibirica*] (see Timber), constituting the forests of Arctic Europe and Asia; and in America, from *P. mitis, P. rigida, P. australis*, and other species. N. Europe is much the larger producer.

The process of distillation is commonly performed as follows. The roots and bases of the trees, which are valueless as timber, are closely packed in huge stacks (30,000–70,000 cub. ft.), and covered with a thick layer of turf, moss, and earth, heavily beaten down. The stack is built over a conical cavity in the ground, and if possible on a hill-side. A section of the oven and receiver is shown in Fig. 1182. Fire being applied, combustion is allowed to proceed very slowly and without flame, requiring 1–4 weeks for its completion, according to the bulk of the stack. The products of the downward distillation (mainly tar) collect in the cavity, and are discharged thence into receptacles. A great improvement on this rude plan is the employment of wrought-iron stills with refrigerating condensers. By their use, the yield of tar obtained from air-dried pine-wood is 14 per cent., and from the roots, 16–20 per cent.; in addition, much pyroligneous acid and turpentine-oil is saved. Tar is usually transported in barrels of 31½ gal. Its approximate London market value is 13–17*s.* a bar. for Archangel, and 18*s.* for Stockholm. Its widespread use as a preservative application to wood is sufficiently familiar.

1182.



Our imports of tar in 1880 were 105,449 bar., value 73,772*l.*, from Russia; 10,719 bar., 7138*l.*, from the United States; 3877 bar., 3219*l.*, from Sweden; and 11,227 bar., 6465*l.*, from other countries; total, 131,272 bar., 90,594*l.* Our exports in the same year to all countries were 9740 bar., 10,048*l.* The imports show a gradual diminution in quantity from 174,679 bar. in 1877; and in value, from 152,969*l.* in 1876. Russian tar is manufactured in Finland and shipped from various ports in the Gulf of Bothnia (Uleaborg, Gamla and Ny Carleby, Jacobsstad, Christinestad), and from Archangel and Onega on the White Sea; while some is produced in Volhynia, and finds its way by the Dnieper to the Black Sea. The Swedish localities of production are mainly about Umea and Lulea, where iron stills are in general use, thus accounting for the superior price of Stockholm tar. Our imports from Sweden fell from 8083 bar. in 1877, to 701 in 1878, and recovered to 4319 in 1879. Our imports from the United States were 29,771 bar. in 1877, since which date they have constantly receded. New York exported 7679 bar. in 1878, and 7031 in 1879; of the former, 1050 bar. went to N. Europe, and 6070 to S. America, E. and W. Indies, &c. Philadelphia, in 1879, exported 1968 bar. of tar and pitch. Boston, in 1880, received 8398 bar., and exported 1088. Wilmington (N. Carolina), in 1878, sent 32,008 bar. coastwise, and 31,176 abroad; total value, 19,461*l.* The exports of tar from Finland were 143,174 bar. in 1878, 138,730 in 1879, and 129,669 in 1880.

2. *Beech-tar.*—The wood of the beech, *Fagus sylvatica* (see Timber), affords about 10 per cent. of tar, which is considered by some authorities the best source of creasote.

3. *Birch-tar.*—The wood and bark of *Betula alba* afford a tar whose chief importance lies in its being the source of the empyreumatic oil used in the preparation of Russia-leather (see Oils and Fatty Substances, pp. 1417–8).

4. *Dummele.*—This name is applied in Ceylon to a tar extracted by the moormen from the wood of *Sethia indica* [*Erythroxylon monogynum*], of the Circars, Travancore mountains, Mysore, Malabar, and Ceylon. The wood is packed into an earthen pot (*chatty*) with a narrow mouth; this is inverted over a second pot, and surrounded by fire. The tar thus distilled is soluble in ether, alcohol, and turpentine, and is an excellent preservative of timber. It is not a commercial article, but might become so.

5. *Ganda.*—The natives of the Himálayas prepare a tar from dry chips of the *ganda* tree (*Pinus longifolia*) of their district. The process is much the same as with *dummele.* The product from this species and *P. excelsa* and *Cedrus Deodara*, with due care, is said to be quite equal to the Stockholm tar imported from Europe, and much cheaper.

6. *Juniper-tar* (Fr., *Huile de Cade*).—This was originally obtained by the destructive distillation of the wood of *Juniperus oxycedrus*, a native of the Mediterranean region. The modern article is of doubtful origin, and much resembles Stockholm tar.

7. *Teak-tar.*—The wood of *Tectona grandis* (see Timber—Teak) yields about 5 per cent. of tar by the crude native method of distilling it. The wood is best used 3 months after felling. Probably the roots would yield much more. It is only used medicinally by the natives of some parts of India.

A tar is also extracted by the Moors from the root of *Callitris quadrivalvis* (see Sandarach), and applied to wounds on draught animals.

Tendoo and Gaup.—These names are applied respectively to a resin from the trunk and a gum from the fruit of *Diospyros glutinosa* [*Embyropteris glutinifera*], a native of the Indian Peninsula, Travancore, Assam, and Bengal. Both products are said to be used for caulking boats, and preserving fishing-nets, but they are not objects of commerce. Further research as to their supply and applicability is desirable.

Thus, Scrape, or Common Frankincense (Fr., *Galipot, Barras*).—These terms are applied to the turpentine which concretes upon the trunks of the various species whence that oleo-resin is derived (see pp. 1686–92). In the French department of Landes, the collection is commenced immediately after the conclusion of the turpentine-harvest. The impoverished exudation from the latest wounds, escaping when the air-temperature is not high, and being probably less rich in essential oil, dries in stalactitic masses, reaching from the incision to the base of the tree. These are separately collected in the winter. In France, the term *galipot* is restricted to the concretions along the scars, which can be gathered without admixture with bark fragments; while *barras* is applied to those portions which can only be detached by scraping, and are thus much contaminated with woody débris. The commercial article occurs in solid or softish masses, yellowish-white to greenish in colour, granular in texture, and completely soluble in alcohol. It differs from the turpentines mainly in containing less essential oil, and is used for similar purposes. Its approximate London market value is 16–20*s.* a cwt.

Tolu (Fr., *Baume de Tolu*; Ger., *Tolubalsam*).—This balsam or rather resin is afforded by *Myroxylon Toluifera* [*Toluifera Balsamum, Myrospermum Toluiferum*], a native of Venezuela and New Granada (Colombia), probably also of Brazil and Ecuador, and identical, according to Bentley, and Trimen, with *Myroxylon punctatum*, an inhabitant of nearly the whole northern part of S. America. Weir is of opinion that the tree is plentifully scattered throughout the *montaña* around Plato and other small ports on the right bank of the Magdalena. Another writer states that the balsam is largely collected in the Sinu valley, and the forests separating that river from the Cauca; but none seems to be gathered in Venezuela. The tree is never found in the low tracts adjoining the rivers, but in the higher rolling ground beyond, where the soil is dry. The balsam-harvest lasts about 8 months, from July to March–April. The collection is effected by V-shaped incisions, at the apex of which, a little hollow is made in the bark and wood, to facilitate the fixing of tea-cup-like calabashes, as receptacles for the exudation. About 20 incisions are commonly made within the space accessible to a man standing on the ground; when this portion of the trunk affords no further space for new incisions, a higher section is sometimes attacked by the aid of a rude stage. The contents of the calabashes are emptied at intervals—(they fill in one month when the flow is good)—into hide bags slung on donkeys, for conveyance to the river-ports, where the balsam is transferred to cylindrical tins of about 10 lb. capacity for export. In some districts no calabashes are used, the exudation finding its way down the trunk into a large *Calathea*-leaf.

The balsam is a light-brown, viscid or fluid resin, gradually hardening to brittleness, but readily softened by warmth; of sp. gr. 1·2, agreeable odour, and slight aromatic flavour. It is soluble in alcohol and chloroform completely, and in ether partially; but is very slightly dissolved by essential oils and carbon bisulphide, whence the detection of such adulterants as rosin is rendered easy. The use of liquid storax (see p. 1682) as an adulterant is said to occur in the

United States. It is employed slightly in medicine, but more in perfumery. Its London market value is about 3–4*s*. a lb. It is exported from Colombian (New Granada) ports:—The shipments from Santa Marta were 2002 lb. in 1870, 2183 in 1871, and 1206 in 1872; and from Savanilla, 27,180 *kilo.* in 1876.

Tragacanth.—Using the term "tragacanth" in a generic sense, the species to be described are:—(1) Tragacanth proper, (2) Indian tragacanth, or *kuteera*, (3) African tragacanth, (4) Hog tragacanth, or simply "hog gum," which must be distinguished from the gum bearing the same name described on p. 1654.

1. *Tragacanth proper* (Fr., *Adragante*; Ger., *Traganth*).—True tragacanth is a gummy exudation afforded by the stems of several species of *Astragalus*, of which the principal are the following:—*A. gummifer*, occurring on Lebanon and Hermon in Syria, Beryt Dagh in Catalonia, Arjish Dagh (Argæus) in Central Asia Minor, and in Armenia and N. Kurdistan; *A. microcephalus*, extending from S.-W. Asia Minor to Turkish and Russian Armenia; *A. adscendens*, a native of the mountains of S.-W. Persia at 9000–10,000 ft.; *A. brachycalyx*, on the mountains of Persian Kurdistan; *A. pycnoclados*, on the high mountains of Avroman and Stahn, Persia; *A. kurdicus*, on the mountains of Cilicia and Cappadocia, extending thence into Kurdistan; *A. stromatodes*, at 5000 ft. on the Akker Dagh range, N. Syria; *A. verus*, in N.-W. Persia and Asia Minor; *A. Parnassi*, var. *cylleneus*, on the northern mountains of the Morea; and *A. leioclados.*

The mode of secretion of tragacanth has been discussed under the generalities commencing this article (see p. 1620). Reference must here be made to Giraud's researches, quoted in the Bibliography at p. 1695, which throw quite a new light upon the subject; according to his analysis, tragacanth contains only 8–10 per cent. of soluble gum, and about 60 of pectinous principle, apparently identical with Frémy's pectose. The collection of the gum in Asia Minor and Armenia is described by Tozer, Maltass, Hamilton, Von Scherzer, and others. The principal localities for it are the district of Angora; Isbarta, Buldur, and Yalavatz, north of the Gulf of Adalia; the Ali Dagh range between Tarsous and Kaisarieh, and the hilly country eastward as far as the Euphrates valley; the elevated Bingol Dagh range, south of Erzeroum; and throughout Kurdistan, from Mush for 500 miles in a S.-E. direction to the Persian province of Luristan. About the first week in August, the gum is seen adhering to the stems and branches, looking from a distance almost like down, but later in the season it usually has fallen off, so that the ground below is strewn with it. The common way of obtaining it, however, is to cut the plant and leave it to bleed; after some days, when the gum has exuded and hardened, the collectors return and gather it. The ground is often swept clean to receive the droppings. The incisions are sometimes cuts made into the bark, sometimes simply punctures with a knife-point. In Persia, the production of the gum is spread over an area of 300 miles long by 100–150 broad, between Gilpaigon and Kashan, southward to the Mahomed Suma range, N.-E. of Shiraz. The tragacanth collected in Persia and Kurdistan is mostly of spontaneous exudation.

The composition of tragacanth has already been stated. The best samples are dull-white, translucent, lustreless, flexible, strong, odourless, and almost flavourless. It occurs in two principal forms, distinguished as "leaf" and "vermicelli." The latter consists of vermiform pieces; the former, of flattish strips, 1–3 in. long and ¼–1 in. wide. Immersed in water, it swells up and finally disintegrates. It is readily soluble in alkaline liquids. Its chief use is for imparting firmness to lozenges and pill-masses, and in other pharmaceutical preparations; the commoner kinds are employed in a mucilage for "marbling" books. The approximate London market values are 10–20*l.* a cwt. for leaf, and 2–10*l.* for low to good sorts, the price depending upon the purity and whiteness. One of the chief export marts is Smyrna, whither it is brought from the interior (Kaisarieh, Konieh, &c.) in a very crude state in bags of about 2 *quintals*, in August, and where it is largely assorted by Spanish Jews for the European market. The annual export from Smyrna is stated at about 4500 *quintals* (of 100 lb.), value 65,000*l.* It is also shipped from Constantinople and the Persian Gulf. The Persian and Kurdistan article is despatched from Bagdad, which sent 555 cwt., value 2259*l.*, to India and Europe in 1878. This article is erroneously termed "Syrian" in English drug sales. Mersine [Musyna] exported 245 tons, value 31,800*l.*, in 1880.

2. *Indian Tragacanth or Kuteera.*—Gums bearing a close resemblance to tragacanth are produced by several Indian plants. One of the most important is *Cochlospermum* [*Bombax*] *Gossypium*, a native of the dry hills of Garhwal, Bundelkund, Berar, Orissa, and the Deccan, also commonly planted near temples. The gum is white, semi-transparent, in striated pieces which are very much twisted and contorted; it is used locally by shoemakers. This variety is considered inferior to the gum yielded by *Sterculia* [*Cavallium*] *urens*, a native of N.-W. India, Assam, Behar, the E. and W. Peninsulas, and Ceylon. Several other species of *Sterculia* are accredited with affording an almost identical product. The range of utility of this class of gums is very limited, competing only with the lowest grades of true tragacanth, for which there is but slight demand in European markets.

3. *African Tragacanth.*—This variety is derived from *Sterculia Tragacantha*, an abundant native of W. Africa, from Senegambia to the Congo. The gum is afforded in great quantity, and commonly finds its way into parcels of Senegal (Arabic) gum. It forms colourless or yellowish stalactitic masses, transparent in very thin slices. It bears the closest general resemblance to the produce of Indian species of *Sterculia*, just described.

4. *Hog Tragacanth, or Hog Gum.*—These terms, like that of "Bassora gum," seem to be applied to mixtures of various cheap and inferior gums, placed on the market at intervals with a view to being foisted off as tragacanth. At Smyrna, tragacanth is mixed with gums termed "Mosul" and "Caramania." The former appears to be very inferior tragacanth; while the latter is referred to the exudations of almond- and plum-trees, and is usually treated with white-lead to hide its darker colour. It is evident that the Indian *Sterculiæ* also contribute occasionally to the supplies of hog tragacanth. Almost the only application of this inferior material is as a mucilage for "marbling" book-edges, for which purpose it is not superior to mucilages obtained from linseed, quince-seed, or elm-bark. (See also Hog gum, p. 1654.)

Turpentine.—This name is applied to a number of liquid oleo-resins obtained chiefly from the *Coniferæ*. They will receive separate description in the following order :—(1) Aleppo, (2) Canadian, (3) Carpathian, (4) Chian, (5) Common, (6) Hungarian, (7) Strasburg, (8) Venice.

1. *Aleppo turpentine.*—The Aleppo pine (*Pinus Halepensis*) in Provence is tapped much in the same way as the maritime pine in W. France, and yields similar but less valuable products. Usually the tree is bled when it has attained a diameter of 8–12 in. The incisions (*surlés*) are about 4 in. wide, and are prolonged by a fresh cut upwards once every 19 days, till their length amounts to about 1 ft. The exudation is received in holes made in the ground at the foot of the tree. Freshly caught, it is called *périme vierge*; the cakes of resin prepared from it are termed *rare*. The yield of a good tree should be 13–15 lb. of crude turpentine annually for about 20 years.

2. *Canadian turpentine* (FR., *Baume du Canada*, *Térébinthine du Canada*, *T. du Sapin baumier*, *Faux baume de Giléad*; GER., *Canada balsam*).—Canadian turpentine, or, as it is generally called, "Canada balsam," is produced by the "balsam fir" or "balm of Gilead fir" (*Pinus* [*Abies*] *balsamea*), and in a minor degree by the "small-fruited" or "double balsam fir" (*P. Fraseri*), and a closely similar article by the hemlock spruce (*P.* [*A.*] *canadensis*). The first species is very abundant in the N. and W. United States, Nova Scotia, and Canada, up to 62° N. lat. The second occurs on the mountains of Pennsylvania, Virginia, and southward on the highest Alleghanies. The third (see Tannin) extends throughout British America to Alaska. Of these three, the first only will receive further description here.

The balsam fir prefers wet or marshy soil, in cold hilly regions, though thriving on comparatively dry upland, and in almost any soil. Its growth is rapid, but its size is small—30–40 ft. high, and 6–8 in. diam. It is thus of little value for timber, and is utilized only for its oleo-resin, which is generally more abundant in the flourishing smooth-barked trees of low damp lands than in the stunted growths of the mountains. The tree is very subject to the attacks of a bark-mining beetle, belonging to the genus *Tomicus*, which is rapidly destroying the forests, and can only be checked by felling all trees that are affected, burning the bark and with it the colonies of larvæ.

The oleo-resin collects in utricules, which cause a protuberance in the exterior layers of the bark. The tapping is performed in a peculiar manner. The gatherers are provided with small cans, having a sharp-edged iron tube proceeding from the top. By this tube, the blisters are pierced one by one, the liquid flowing down the tube until the can is full. Boys are sent up into the branches, while the father works about the lower part of the tree, this industry being followed by families, and confined to the poorest colonists and the Indians. A large rich tree may yield 1 lb. of oleo-resin, but the average is about ½ lb. A man and 2 children may collect 1 gal. in a day, while a man alone would not exceed ½ gal. The gathering cannot be prosecuted during rain, nor even in the same day, as drops of water mixing with the exudation render it milky and unsaleable. The season lasts from about 15 June to 15 August or 1 September, or between the dates of the disappearance of snow from the mountains and its reappearance. Near the villages and on partially cleared land, small quantities are collected in May. A tree should not be pierced in two successive years; 2–3 years' rest should intervene, and even then the subsequent yield never equals what it was the first time.

The freshly-drawn oleo-resin is a honey-like, transparent, straw-coloured to greenish body, slowly thickening and darkening by keeping, but always retaining its transparency, and never crystallizing. Its odour is pleasant and aromatic; its flavour, bitterish and feebly acrid, but not objectionable; its sp. gr., about 0·998 at 14½° (58° F.). It forms a perfect solution of acid reaction with chloroform, benzol, ether, and warm amylic alcohol; the mixture with carbon bisulphide is turbid; it dissolves partially in glacial acetic acid, acetone, and absolute alcohol, leaving, after boiling and cooling, a considerable amorphous residue. This latter character distinguishes it from rosin and Venice turpentine, which are completely dissolved by these menstrua, and even by spirit of wine containing 70–75 per cent. of alcohol. Its composition varies greatly within certain limits, but may be approximately stated as 24 per cent. of essential oil, 60 of resin soluble in boiling alcohol, and 16 of resin soluble in ether. Its medicinal properties resemble those of copaiba, but it is now almost obsolete in pharmacy. Its physical qualities render it valuable for mounting microscopic objects, and it is used for making varnish. It is obtained chiefly in Lower Canada, and shipped from Montreal and Quebec, in kegs and casks. The annual crop varies from 2000 to 7000 gal. The approximate London market value is 8*d.* a lb.

3. *Carpathian balsam* (**Fr.**, *Térébinthine des Carpathes*).—This turpentine is yielded by the Cembran, Siberian, or Swiss stone pine (*Pinus Cembra*), a tree forming the last zone of forestal vegetation, and occurring in France only on the Briançonnais Alps. The bark contains reservoirs of a liquid, colourless, limpid oleo-resin, having a pleasant odour, and acrid bitter flavour. It is rare in commerce.

4. *Chian or Cyprian turpentine* (**Fr.**, *Térébinthine* [*Baume*] *de Chio* [*Chypres*]; **Ger.**, *Chios, Cyprischer Terpentin*).—This is a product of *Pistachia Terebinthus*, a shrub or tree of the Mediterranean islands and shores and Asia Minor, extending as *P. palæstina* to Syria and Palestine, as *P. cabulica* eastward to Afghanistan and Beluchistan, and as *P. atlantica* to N. Africa and the Canaries. The commercial source of the oleo-resin is at present exclusively the island of Chios (Scio), but the wide distribution of the plant would facilitate the increase of the supply if necessary. In the Algerian forests, it is abundant as a large tree (50 ft. high and 6 ft. circ.), and affords a spontaneous exudation during the hot weather amounting to 7–14 oz. This spontaneous exudation is considered superior to that which is induced by incising or puncturing the bark, but is much less plentiful. Chios supplies the world's needs of this turpentine from about 1000 trees, some being 800–900 years old. Longitudinal incisions are made in the lower portion of the stems about April, when the trees are in full bloom. These incisions are prolonged upwards more or less, according to the quantity of turpentine it is desired to obtain, the resinous juice being secreted in special cells in the bark. The incisions are renewed every year. The annual crop of Chios is about 300–400 *okes* (of 2·82 lb.), this being the quantity ordinarily demanded by the market; but in an exceptional case, probably 3000–4000 *okes* could be secured in one season. The flow from the incisions continues during the whole summer, and the quantity amounts to about 10–11 oz. A century ago, the turpentine was caught from the incisions in little earthenware cups suspended from the stems; but the low prices ruling in more recent years favoured carelessness in the collecting, and the common practice of the present day is to leave the exudation to harden on the stem, or fall upon the sand or stones beneath. Hence the impure and inferior character of the modern drug. It undergoes some purification locally by being melted in the sun and strained through small baskets. The trade is almost exclusively in the hands of the Jews.

The sole use of this turpentine in England is for medicinal purposes. It had long been virtually obsolete, when Dr. Clay's success in treating cancer with it recalled it into notice, and created a demand for it which was greater than could be immediately supplied, whence much sophistication and substitution were resorted to, the favourite materials apparently being Canadian and common turpentine. Its chief characteristics are as follows. The flavour is feebly aromatic and terebinthinous, quite devoid of bitterness and acridity. The odour is pleasantly aromatic, faintly terebinthinous, and quite characteristic; it has been likened to elemi and to fennel, and is very distinct from coniferous oleo-resins. The consistence varies greatly with age. The solubility of the drug in 1 vol. of warm rectified alcohol (60 o.p.) is almost complete; it is not quite bright, but does not deposit to any large extent on cooling. Many of the coniferous resins may thus be detected. Organic remains are always present in Chian turpentine, from the method of collection; these may be studied as additional evidence of the origin of the drug under examination.

5. *Common* [*American and Bordeaux*] *Turpentine* (**Fr.**, *Térébinthine commune*; **Ger.**, *Gemeiner Terpentin*).—Common turpentine is afforded by a number of species of pine in both hemispheres. In Europe, they are chiefly the Scotch pine (*Pinus sylvestris*) in Finland and Russia; the Corsican pine (*P. Laricio*) in Austria and Corsica; the maritime fir or *pin maritime* (*P. Pinaster* [*maritima*]) in S.-W. France. In Asia, there are *P. excelsa* in Nepal and the Himálayas, *P. longifolia* in the Himálayas, *P. Gerardiana* in the Himálayas, *P. Massoniana* in Japan and Burma, and *P. Khasyana* and *P. Latteri* in Burma. In America, the swamp or Georgia pitch pine (*P. australis* [*palustris*]) and the loblolly (*P. Tæda*) in the S. United States, and the common red pine (*P. resinosa*) in Canada. The cultivation of these trees will be described in the article on Timber. In the present article, attention will be confined to their resinous exudations.

The so-called "pine barrens" of the United States extend from Virginia to the Mexican Gulf, especially through N. and S. Carolina, Georgia, and Alabama, but the extraction of turpentine is an industry mainly developed in N. Carolina. In winter (November–March), the "boxing" is carried on. This consists in cutting cavities in the tree, at 6–12 in. above the ground, and shaped like a distended waistcoat-pocket, the lower lip being cut horizontally, the upper one arched, and the bottom of the box being about 4 in. below the former, and 8–10 in. below the latter. The capacity of each "box" is about 2–3 pints, and its purpose is to form a receptacle for the exudation. The boxes are cut by means of a specially-shaped axe, and considerable skill is required to wield it properly, a chief object being to attain the desired capacity while approaching as little as possible the heart of the tree, and thereby endangering its life. An expert may make a box in 10 minutes, or about 50–60 in a day. The box being made and carefully cleaned of all chips, the exudation is induced by removing with the axe a thin slice from the upper lip of the box, including the bark and about 2 or 3 rings of the wood. There are commonly 3 boxes in a tree of 18 in. diam., it being a good rule to have at least 6 in. of face between the boxes. Some authorities are of opinion that it is beneficial to restrict operations to the northern face of the tree, the turpentine thereby retaining more of the volatile constituent, and the boxes being less exposed to the dust and leaves blown about by the southerly winds of summer. From the pared upper lip of the box, the sap begins to flow about the middle of March. From that time, the surface of the wound requires to be renewed every 7–10 days, which is effected by slicing off about ⅛ in. from its face, the object being merely to expose fresh tissue as fast as it becomes clogged by the exudation. The latter mainly collects in the box, and is dipped out at intervals by special ladles, and barrelled. By the repeated slicing of the upper lip of the box, the wound ascends the tree to a height of 12–15 ft., ladders being used in the later years during which the operation is prolonged. The higher the wound has been carried, the greater the surface passed over by the exudation on its way to the box, and the greater the proportion which solidifies prematurely on the wound. This is the portion which is termed "scrape" in America (see Thus, p. 1684). The liquid portion which collects in the boxes is called "dip," in contradistinction. The scrape is removed about once a year; by allowing it to accumulate excessively, the yield of dip is much reduced. The 1st year's flow of a newly-boxed tree is known as "virgin dip," and is separately barrelled, being of superior quality. All leaves and chips should be cleared away from around the base of the trees, to avoid the outbreak of fire, and afford no harbour for insects.

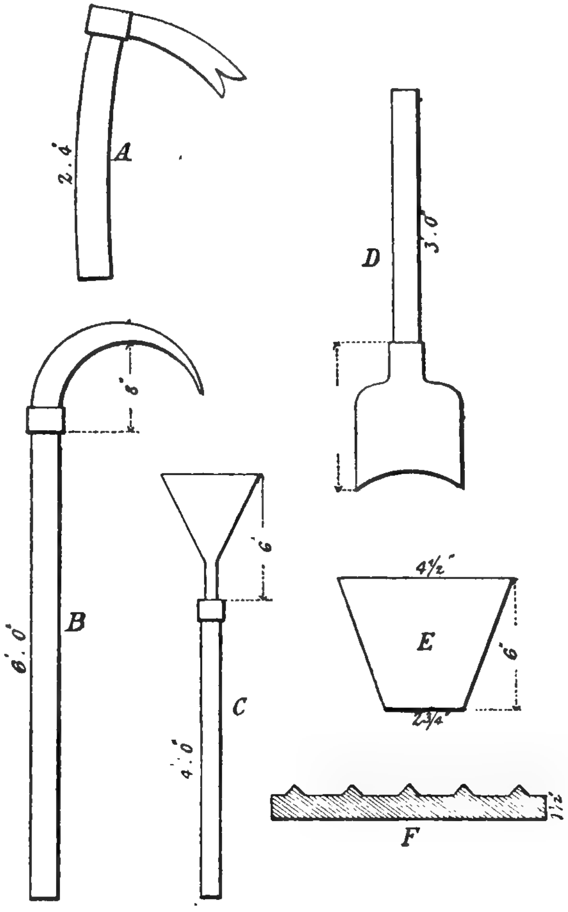
The crude turpentine has to undergo a process of distillation, to separate the "rosin" from the "spirit," "oil," or "essence" of turpentine. This distillation is carried on mainly on the streams near the localities of production. During the Civil War, large quantities of the crude oleo-resin were shipped to England for distillation, but this has long since ceased to be the case. The little sent into the N. States undistilled is used for making printing-ink. The production in the United States in 1876 was stated at 300,000 casks turpentine-spirit, and 1,500,000 barrels (of 280 lb.) of rosin.

Both rosin and turpentine-spirit were made in Canada, during the American Civil War, from the common red pine (*Pinus resinosa*), which grows abundantly in the N. counties of Ontario. The turpentine obtained from it is not identical in its qualities with that of the S. States, but forms a convenient substitute. Since the supplies of the southern article have resumed their normal condition, this manufacture has been abandoned.

In the French departments of Landes and Gironde, the extraction (*gemmage*) of the crude oleo-resin is conducted in a much more rational manner. Towards the end of February or beginning of March, preparations are commenced by thinning down the rough bark till only the last cortical layers remain covering the sap-wood, thus presenting a smooth even surface. The thinning is confined to the space which will be operated on during the current season, allowing a margin of 4 in. in height and ¾–1¼ in. in width, so as to prevent bark fragments from falling into the receptacle placed to catch the exudation, and avoid the blunting of the edge of the instrument used in making the incision. The next operation, generally performed about 1st–10th March, consists in cutting the resiniferous ducts by means of the *abchotte*. The workman cuts into the foot of the tree an incision with a convex top, termed a *carre*, measuring 4 in. wide, 1¼ in. high, and ½ in. deep. The crude turpentine (*gemme*) escapes in viscous transparent drops, thickening by exposure to the air, a portion adhering to the *carre*, while the more liquid remainder flows into a receptacle. This latter was formerly a hole made in the earth at the foot of the tree, and named *crot*; but since 1860, little earthenware dishes have come into general use, the oleo-resin being conducted into them by strips of zinc, called *crampons*. The renewal of the wound (*piquage*) is performed every 5–7 days. When the dishes are sufficiently full, their contents are emptied into a wooden basket termed an *escouarte*, the dishes are replaced, and the oleo-resin is conveyed to large reservoirs known as *barcous*, built of wood or bricks here and there in the forest, where it remains till required for manufacture. By the *piquage*, the *carre* constantly increases in height, but never exceeds certain dimensions. These have been recently fixed at the following figures:—Height: 1st year, 22 in.; 2nd, 51 in.; 3rd, 80 in.; 4th, 109 in.; 5th, 148 in.; width, 3½ in.; depth, ½ in., measured from a line parallel with the red part of the bark.

There are two modes of *gemmage: à mort* and *à vie*. The former is applied only to trees which are to be felled, in which case, it is desired to extract the greatest possible quantity of turpentine in the shortest time, and with this object, a number (2–6) *carres* are made simultaneously. The latter system (*à vie*) is adopted with trees which are to remain growing (called *pins de place*), and in which never more than one *carre* is opened at a time. When the first, at the end of 5 years, has a height of 148 in., the tree is allowed to rest for several years; a fresh one may then be made at a distance of not less than 6–8 in. from the last. The old-fashioned plan of collecting the turpentine in a hole in the ground is termed *gemmage au crot*; the modern plan of using earthenware dishes is known as the *système Hugues*. By the latter, the yield is increased ⅕, and the value 10 *francs* (8*s.*) a barrel, while the additional cost is about 5*c.* (2½*d.*) a tree per annum. The *gemmage à mort*, on trees which are to be felled, is performed as soon as they are large enough to support a *carre*, which is when they are 16 in. round, usually attained at an age of 20 years. Until 1877, in the government forests, the *gemmage à vie* was commenced on reserved timber at a circumference of 39 in., but this has since been increased to 43 in., when the pines are 30–35 years old. The mean annual yield per *hectare* (of 2½ acres) of turpentine and "thus" varies from 240 *kilo.* (of 2·2 lb.) in the younger forests, to 450 *kilo.* in those where the trees are mostly 40–70 years of age. The yield, however, fluctuates greatly both in quality and quantity, according to the season and other varying conditions.

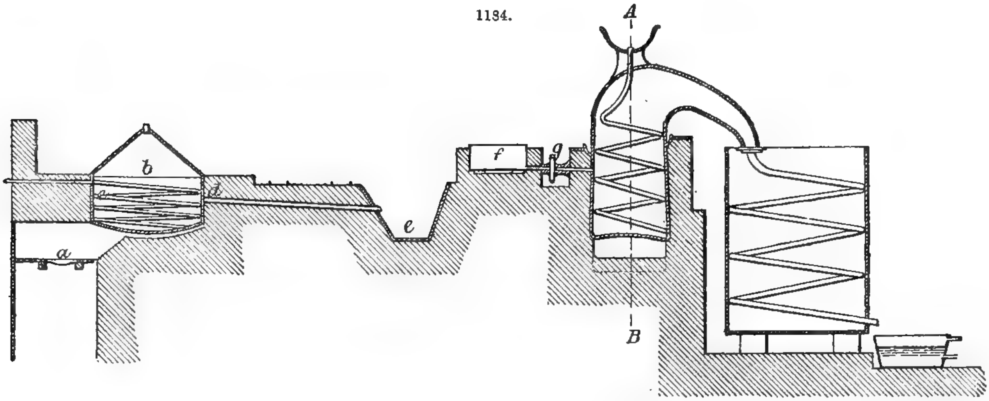
1183.



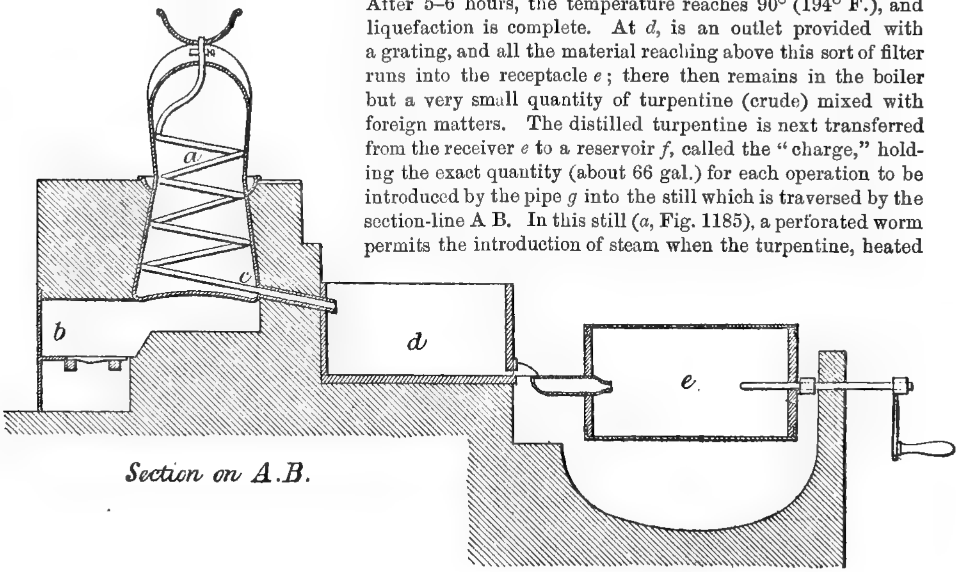
The tools employed by the *résiniers* or collectors are shown in Fig. 1183. The *abchotte* or *abchot* A is a sort of axe, used to make the *carres* and to renew the wound. The *barrasquite* B has a sharp, narrow, curved blade, while the *pousse* C is broad and straight; these two implements are employed in detaching the *barras* and *galipot* (see Thus), as well as in the barking operation, the *barrasquite* being adapted for use only at an inclination, and not above a height of about 8 ft. The *pelle* serves for barking the lower part of the tree, for constructing and cleaning the *crots*, according to the old mode of *gemmage*, and for removing the oleo-resin therefrom to deposit it in the *escouarte*. The little glazed earthenware pot E receives the exudation, which latter is removed from it by a small iron spatula. The *crampon* F is a curved zinc blade armed with 5 teeth; it is driven into the *carre* to conduct the flow of oleo-resin to the receptacle.

The *gemmage* of the *pin maritime* is almost confined to the basin of the Garonne. Attempts were made in Sarthe or Mayenne, and in Sologne, but unsatisfactory results caused their abandonment. The operation was formerly carried on on the Mediterranean shore, but has been given up in face of the enormous production of the Landes. It is recorded that the extraordinary cold of last winter (1880–1) killed nearly all the *pins maritimes* in N. and Central France, causing enormous losses, notably in Sologne. The occasion was seized by Prilleux to test the correctness of the popular belief that frost destroys the oleo-resin; the result of his investigation was that the dry wood of trees not killed by frost gave only 2–3 per cent. of resin, while those which were killed gave 3-4 per cent. This probably signifies that the dead tissue was not capable of retaining any of the oleo-resin, rather than that the frost actually augmented the secretion. About 600,000 *hectares* of this pine now exist in the Landes and on the sand-dunes. The annual exports now amount to the following figures:—To Belgium, England, and Germany, 3 million *fr.* worth of turpentine-spirit; to Germany and England, 2½ million *fr.* worth of distillation residues (rosin, pitch); finally, to Germany, England, and Holland, ½ million *fr.* worth of thus, tar, &c. The consumption in France is estimated at 9 million *fr.* The total harvest in 1874 was 29,395,417 *kilo.* (of 2·2 lb.).

1184.



1185.



Section on A.B.

Many improvements in the distillation of the crude oleo-resin and its products have of late years been introduced in France. The arrangement of the apparatus for the first distillation, the separation of the rosin and the spirit of turpentine, is shown in longitudinal section in Fig. 1184, and in cross section on the line A B in Fig. 1185. The crude oleo-resin, after a certain amount of mechanical purification by straining and settling, is placed in the boiler *b*, fitted with a movable lid, heated by the fire *a*, and furnished with a steam-coil *c*. After 5–6 hours, the temperature reaches 90° (194° F.), and liquefaction is complete. At *d*, is an outlet provided with a grating, and all the material reaching above this sort of filter runs into the receptacle *e*; there then remains in the boiler but a very small quantity of turpentine (crude) mixed with foreign matters. The distilled turpentine is next transferred from the receiver *e* to a reservoir *f*, called the "charge," holding the exact quantity (about 66 gal.) for each operation to be introduced by the pipe *g* into the still which is traversed by the section-line A B. In this still (*a*, Fig. 1185), a perforated worm permits the introduction of steam when the turpentine, heated by the fire *b*, has attained a temperature of 135° (275° F.). Effervescence ensues, and the "spirit" or "essence" separates completely. At *c*, is an opening closed by a wooden bung, and carefully luted. When the spirit ceases to pass into the serpentine receiver (*h*, Fig. 1184), the operation is suspended; the rosin, at a temperature of about 130° (266° F.), escapes at *c* into a box *d*, and thence into a cylinder *e* formed of very fine metallic gauze. This cylinder is made to revolve on its axis; the rosin falls through into a receptacle, while an unimportant residue remains inside. The rosin may be at once barrelled and shipped. The spirit leaving the serpentine cooler (*h*, Fig. 1184), being cloudy, is placed in large earthenware jars holding about 66 gal. and with clay-luted covers, recalling the *tinajas* used in the olive-oil industry (see p. 1403). Here it remains 4–5 days, and deposits the little remaining impurity. Copper vessels are sometimes substituted for these jars, and with advantage.

In some works, a few improvements have been made in the foregoing processes. The boiler *b* (Fig. 1184) may be fitted with an agitator, thus preventing solid matters from burning on to the bottom. Its cover may carry rims for containing water to condense the vapours. Thermometers may be placed in the boiler and still for regulating the temperature. Finally, it has been attempted to employ steam-heat throughout, as being more easily controlled.

The treatment of the residues is described under Pitch, Rosin, and Tar (pp. 1678–81, 1683–4).

The crude turpentine commonly reaches the works in barrels containing about 50½ gal., and weighing about 517 lb. The yield from this by the oldest method was only 33 lb. of turpentine-spirit, which was increased to 83 lb. by using hot water in the still of Fig. 1185, while by the adoption of steam, the result is 99 lb. of turpentine-spirit, and about 352 lb. of dry matters. The steam process not only effects a greater yield, but produces a better article, and requires less time and labour.

The Russian method of tapping differs essentially from both the American and the French. The trees, when 20 ft. high below the branches and 3½–7 in. thick, are stripped of a piece of bark about 28 in. wide, and leaving only about 2–3 in. of the trunk undenuded, preferably on the north side. The oleo-resin exudes and becomes inspissated on the barked patch (really forming "thus"), and is scraped off in the following autumn, averaging about 14 oz. to a tree. Next year, the barking is continued in narrow rings for a distance not exceeding 16 in., and the product may amount to 21 oz. In the 3rd year, it reaches about the same figure; in the 4th, it falls back to 14 oz. In the 5th year, 24 in. are removed, but the yield is then small; the barking is stopped in the 6th year, but the tree is left standing for 3–4 years, becoming saturated with oleo-resin, and thus of increased value for the tar-oven (see Tar, p. 1683).

The Indian conifers already named are capable of affording considerable quantities of turpentine, probably at a price which would be remunerative in local markets, but not for export in competition with the American article.

Common turpentine is a honey-like liquid, of strong, disagreeable, characteristic odour, and acrid, bitter, nauseous flavour; it is soluble in alcohol, ether, carbon bisulphide, and fixed and volatile oils. The drying propensity varies, being strongest in the Bordeaux kind. By aqueous distillation, the common turpentines yield 15–30 per cent. of essential oil (see Vegetable Volatile Oils, p. 1431). The consumption of common turpentine in the preparation of varnishes and paints is very extensive. The approximate London market value of American turpentine in casks is 20–30*s*. a cwt.

Turpentine is very rarely exported in its crude state, but the commerce in turpentine-oil (called also "spirit" and "essence") has considerable importance. Our imports were 236,026 cwt., value 271,618*l*., in 1876; 324,145 cwt., 358,000*l*., in 1878; and 271,699 cwt., 378,838*l*., in 1880. Of the last-mentioned, the United States contributed 261,911 cwt., 365,752*l*. Our re-exports in 1880 were 5715 cwt., 8319*l*., to France; 5531 cwt., 6231*l*., to Belgium; 4404 cwt., 6640*l*., to Holland; 8203 cwt., 12,742*l*., to other countries. Our imports from the United States rose from 228,429 cwt. in 1876, to 322,251 in 1878, but receded to 261,911 in 1880. The American port of Boston received 217 bar. crude turpentine and 6546 bar. turpentine-spirit in 1880, and exported 730 bar. of the latter. New York exported 135 bar. crude turpentine in 1878, and 58 in 1879; and 17,213 bar. turpentine-spirit in 1878 and 5824 in 1879; of the spirit shipped in 1878, 4814 bar. came to Great Britain, 2023 bar. went to N. Europe, 1238 bar. to other Europe, 9107 bar. to S. America, the E. and W. Indies, &c. Wilmington, in 1878, sent 11,024 bar. spirit coastwise, and exported 107,152 bar., total value, 266,927*l*.; and of crude, 3087 bar. coastwise and 1449 abroad, total value 1844*l*. Savannah, in 1879, exported 512,268 gal. turpentine, of which, 274,717 gal. came to British ports; in 1880, the figures were 21,743 bar. spirit coastwise, and 605,412 gal. exported. Mobile, in 1880, sent 25,109 bar., value 73,240*l*., to the interior of the United States. The Greek port of Syra, in 1877, sent 112*l*. worth of turpentine to Egypt, 112*l*. to Turkey, and 107*l*. to Great Britain.

6. *Hungarian balsam* (Fr., *Térébinthine d'Hongrie*).—The dwarf or mountain pine (*Pinus Pumilio*) yields a pale-yellow clear liquid, of herbaceous odour and piquant flavour, still known under the name of Hungarian balsam, but hardly met with now in commerce. Its essential oil is used as an inhalation in throat-diseases.

7. *Strassburg turpentine* (Fr., *Térébinthine d'Alsace, de Strasbourg, du sapin,* or *au citron*; Ger., *Strassburger Terpentin*).—This oleo-resin is afforded by *Pinus Picea* [*Abies pectinata*], the silver fir, whose geographical distribution is recorded under Timber. The secretion of the oleo-resin is analogous to that of Canadian turpentine, and its collection is effected in a precisely similar manner. It is afterwards filtered through bark funnels. In all respects, it bears a close resemblance to Canadian turpentine, except in wanting the acrid bitterish flavour of the latter, and any distinct fluorescence. It possesses the properties of common turpentine, with the advantage of a very pleasant odour. It was formerly held in great medicinal esteem, but is now nearly obsolete, and is collected only in very small quantity near Mutzig and Barr, in the Vosges.

8. *Venice or Larch turpentine* (Fr., *Térébinthine de Venise, de Briançon, du mélèze, Suisse*; Ger.,

Venetianischer, Lärchen Terpentin).—This variety of turpentine is obtained from *Pinus Larix* [*Larix europæa*], the European larch (see Timber). The collection of the oleo-resin is carried on chiefly about Mals, Meran, Botzen, and Trent, in the Tyrol; occasionally and in trifling quantity in the Valais, Piedmont, and some places in France. The resiniferous canals of this species are situated mainly in the sap-wood, hence a special mode of extraction is necessary. This consists in cutting a hole to the centre of the tree, at about 1 ft. above ground, in the spring of the year; this is plugged up till the autumn of the same or the following year, when it is opened, and the accumulated oleo-resin is removed in an iron spoon. The yield thus amounts to about ½ lb. yearly, without appreciable damage to the tree. Formerly, in the Piedmontese and French Alps, a number of wide cavities were made, and left open; the product in this case reaches 8 lb. annually, but the timber is greatly injured, and the tree soon ceases to yield at all. It is further urged in support of the modern plugging process that it tends to maintain the transparency and purity of the turpentine.

Venice turpentine is less siccative than any other kind. It is a slightly turbid, translucent, pale-yellow, thick liquid, of less pronounced odour than common turpentine, and an acrid, bitter, aromatic flavour. It has no special medicinal qualities, and is scarcely known now in English dispensing, though useful for plaisters. It is often prescribed in veterinary practice, but is then generally replaced by an artificial compound of rosin and turpentine-oil, the true article being absorbed by the Continental markets.

Varnishes [**Natural**].—This term is applied to a group of products resembling the well-known Burmese lacquer. The chief kinds to be described are (1) Burmese, (2) Cingalese and Indian, (3) Japanese and Chinese.

1. *Burmese.*—The *thit-tsi* of the Burmese is a thick, viscid, greyish, terebinthinous fluid, soon assuming a black colour on exposure to the air. It is contained in every part of the tree called *Melanorrhœa usitatissima*, a native of Burma, and extending to the N.-E. frontier of Silhet and Tippera, and identical with the *kheu* tree of that district. The geographical range may be stated as lying between Munipur (25° N. lat., 94° E. long.) and Tavoy (14° N. lat., 97° E. long). The tree attains its greatest size in the valley of Kubbu, and becomes smaller as it approaches the sea on the Tenasserim coast, where it frequents comparatively low situations. The extraction of the varnish is performed in the following simple manner. Short joints of a thin kind of bamboo, sharpened to a pen-like point at one end, and closed at the other, are thrust slantwise into wounds in the bark of the stem and main boughs, and left for 24–48 hours; on removal, their contents, rarely more than ¼ oz., are emptied into a rattan or bamboo basket previously varnished over. The collecting season lasts while the leaves are off the trees, or from January till April; the bamboos are renewed as often as the juice requires, and are sometimes inserted to the number of 100 in a single tree. A good tree will produce 1½–4 *viss* (of 3½ lb.) annually. At Prome, the pure article fetches about 2*s.* 6*d.* a *viss.* It is commonly adulterated with gingelly-oil. It dissolves in alcohol, turpentine-spirit, and benzol, assuming greater fluidity. It may be diluted with gold-size, which tends to hasten its drying and intensify its colour, while turpentine renders it browner. Locally it is used in enormous quantities in lacquering furniture, temples, idols, varnishing vessels for holding liquids, and paying river-craft. The very long time it occupies in drying has given rise to unfavourable reports on it in European industry.

2. *Cingalese and Indian.*—The black varnish of Ceylon is derived from a species of *Semecarpus*, and similar products are obtained in India from *S. Anacardium* in the Concans, Coromandel, Courtallum, Guzerat, Bengal, and Travancore, from *S. travancorica* in the moist forests of the Tinnevelly and Travancore mountains, and from *Holigarna longifolia*, a common tree about the W. ghats of the Madras presidency, and occurring in Bombay and Bengal. The juice exudes from natural fissures in the bark of the latter, and from the pericarp of the three former, hardening, and assuming a black colour. It forms an excellent varnish, adhering strongly to wood and metal. It is also used as a marking-ink, much the same as the juice of the W. Indian *Anacardium occidentale*, or cashew-nut (see Nuts, p. 1352).

3. *Japanese and Chinese.*—The natural varnish of Japan and China is derived from several species of *Rhus*, whose fruits afford the Japan wax of commerce (see Wax). The stems of the trees are incised at the age of 4–5 years, and the productiveness only lasts for 3 years. The implement used is a sort of double hook called *kaki gama*; with it, a horizontal gash is first made in the bark, then an incision in the centre of the gash. The exudation is collected on an iron spatula, and poured into a vessel suspended from the collector's waist. The incisions are continued upwards till the whole tree has been wounded; it is then cut down, the branches are lopped off, soaked in water for 10–20 days, and abundantly incised. The product is most extensively employed in Japanese and Chinese lacquer-work.

Wood-apple (Ger., *Feroniagummi*).—An arabic-like gum of some industrial importance is afforded by the wood-apple tree (*Feronia elephantum*), an Indian tree, found in Coromandel, the W. coast, Guzerat, and probably Travancore and Burma. The gum is used by dyers, and by painters in miniature and on chintz; it is also employed in making ink and some varnishes, and in preparing fine whitewash. It affords with water a brownish tasteless mucilage, not less adhesive than that of gum arabic. For preparing water-colours, it has a reputation beyond all other gums. It is much cheaper than gum arabic, while apparently equal to it for all purposes.

Xanthorrhœa, Botany Bay, Black-boy, Grass-tree, or Akaroid resin, or Ground-shellac.—These names have been applied at various times to the resins afforded by the *Xanthorrhœas*, of which over half a dozen species have been identified, all indigenous to Australia. In W. Australia, these plants form a principal feature in the vegetation. In Gippsland and the Western Port district of Victoria, *X. australis* abounds on morassy and sandy heaths. All species contain a large quantity of resin, which exudes naturally in such a degree as to cover the base of the leaves and the subterranean portions of the plant, while by crushing the woody stems and sifting or washing away the chips, some 50–60 lb. of the resin may be got from a single specimen. It is usual to distinguish the resins as "red" and "yellow." The former is ascribed by Wiesner exclusively to *X. australis*, and the latter to *X. hastilis*; while *X. arborea* is accredited with the production of both kinds of resin, the fact probably being that it gives a yellow resin becoming superficially red by age. On this point, there is much difference of opinion. All kinds are completely soluble in alcohol, and have a pleasant benzoin-like odour. They have been employed in the manufacture of spirit- and other varnishes, especially for application to metals. Their lime and soda soaps are used in sizing paper. They may also be availed of for the manufacture of picric acid, and an illuminating-gas much cheaper (locally) than coal-gas. The yellow kind is used for staining wood in imitation of cedar. It is said that it can be produced at a cost not exceeding 6*l.* a ton, while possessing a value of 30*l.* a ton in Melbourne for varnish-making purposes.

Miscellaneous.—Besides the foregoing important products, the following species may be recorded as capable of yielding resinous or gummy substances:—

Adenanthera pavonina, in Ceylon, the Peninsula, Travancore, Silhet, and Assam: a gum.

Ægle Marmelos (see Drugs—Bael, p. 793): an amber-coloured gum in small tears, which has been styled as a "good arabic."

Agati grandiflora, in Travancore: a kino-like exudation.

Ailantus excelsa, in the N. Circars and Coimbatore: a gum resembling moringa, only partially soluble.

Ailantus malabarica, in Travancore and Malabar: a dark-brown, homogeneous, soft gum-resin, of fragrant odour, sometimes burnt as incense.

Artocarpus incisa, in Ceylon: a gum or resin called *ratadel.*

Azadirachta indica, in the Peninsula and Assam: said to form a portion of E. India gum (arabic).

Bassia spp. (see Oils, pp. 1392, 1394, 1408, 1410): white milky gums from deep incisions around the trees, but quite useless commercially.

Bauhinia spp. (see Fibrous Substances, p. 921): brownish, mild, cherry-like gums.

Borassus flabelliformis (see Fibrous Substances, pp. 932–3): a black gum.

Calyptranthes caryophyllifolia, in the Peninsula and N. India: "navel-tree" gum, or a kino-like substance.

Careya arborea, in the Peninsula, Concans, and Travancore: a greenish gum.

Cassia spp. (see Drugs, p. 798, Spices): a dark-coloured soluble gum, and from *C. auriculata* an esteemed medicinal resin.

Cedrela Toona, at the foot of the Himálayas: a gum or resin.

Celtis orientalis, in Coromandel, Bengal, and Travancore: a gum resembling cherry.

Ceradia furcata, in S.-W. Africa: a myrrh-like gum-resin (see p. 1625).

Chickrassia tabularis, in the Cunnawady Hills (India): transparent, amber-coloured gum.

Chrysophyllum ramiflorum, the *oaca* or *guariba* of Brazil.

Clusia spp., in Tropical America: chiefly *C. insignis* (a medicinal resin from the flowers), *C. alba*, *C. rosea*, and *C. flava* (pitch-like resins from the stems), *C. Galactodendron* (a *palo-de-vaca* or "cow-tree"), *C. Duca* (*duca* resin, used as incense), *C. Calaba* (a copal resin called *aceite de Maria*).

Cordia Rothii, in Mysore: a gum.

Cycas circinalis, in the S. Concans: a tragacanth-like gum.

Elate sylvestris, common throughout India: a glossy, dark-brown, flexible gum.

Emblica officinalis, common in most parts of India: a brittle gum in stalactitic pieces.

Eriodendron anfractuosum (see Fibrous Substances, p. 948): a vinous-red, semi-soluble gum, resembling moringa.

Erythrina indica, in Coromandel, the Concans, and Assam: a dark-brown opaque gum of no promise.

Garuga pinnata, in Coromandel, Assam, and N. India: an inferior gum called *curvamboo.*

Grevillea robusta, in Australia: a vinous-red, semi-soluble gum resembling moringa.

Grislea tomentosa, in the Peninsula, Concans, W. Ghats, and N. India: a white kuteera-like gum, used in dyeing.

Gyrocarpus Jacquinii, in Coromandel: a black tar-like gum called *poongallee.*

Heritiera littoralis, in Ceylon: a gum or resin called *mendora.*

Jatropha Curcas, in Coromandel and Travancore: a gum.

Lucuma spp., in Brazil: *L. gigantea* (the *jaqua*), *L. fissilis* (the *guaracua*), *L. lasiocarpa* (the *abiarana*), *L. laurifolia* (the *guapeba vermelha*), *L. procera* (the *maçaranduba blanca*).

Macaranga spp., in Malabar and Travancore: a pure light-crimson gum, used for taking impressions.

Melia Azedarach, in N. India, the Deccan, and Concans: a tasteless, soluble gum, resembling wood-apple.

Melia sempervirens, in W. Indies: a gum of small importance.

Mesua ferrea (see Dyestuffs—Nagkassar, p. 864, Perfumes—Nagkassar, p. 1526): an oleoresin that might replace Canadian turpentine.

Michelia Champaca (see Oils—Ilang-ilang, p. 1422): a gum.

Mimusops Elengi, in the Circars, W. Ghats, the Peninsula, and Silhet: the *pogada* gum of Madras.

Nerium suaveolens, in Madras: a dull-red gum.

Opuntia rubescens, in Brazil: a kuteera-like gum.

Panax Colensoi, in New Zealand: an arabic-like gum, occasionally used for adhesive purposes.

Pittosporum spp., in New Zealand: a gum-resin in very small quantity.

Podocarpus cupressina, in Java: a resin (see p. 1625).

Poinciana elata, in Coromandel, Malabar, Guzerat, and Arcot: a gum.

Poinciana regia, in Madagascar: abundance of gum.

Pongamia glabra, in Coromandel, Concans, Deccan, Patna, and Assam: a thick, black, opaque gum.

Prosopis spicigera, in Coromandel: a gum resembling mezquite.

Punica granatum, in Barbary: "pomegranate-gum."

Sapindus spp. (see Nuts—Soap-nut, p. 1360): a gum.

Soymida febrifuga, in Central and S. Provinces and Guzerat: a tolerable gum.

Spondias mangifera, in the Peninsula and Upper India: a mild, insipid, arabic-like gum.

Stereospermum suaveolens, in the Deccan, Bengal, and W. coast: a moringa-like gum.

Tamarindus indica (see Fruit—Tamarinds, p. 1028): a black gum.

Tamarix dioica, from Sind to Assam and Burma: a friable, soluble, pale-yellow gum.

Terminalia spp. (see Oils—Myrobalan, p. 1396, Tannin—Myrobalans): abundance of transparent soluble gum resembling arabic; best and most from *T. belerica.*

Thespesia spp. (see Fibrous Substances, p. 998): a dark, tasteless, cherry-like gum.

Vachellia Farnesiana, in Bengal, Assam, and the Peninsula: an abundance of arabic-like gum.

Wrightia spp., in Ceylon and S. India: gums used for ordinary purposes.

Zizyphus flexuosa, in Nepal: *simli* gum, resembling inferior arabic.

Commerce in Unenumerated Gums and Resins.—Our imports of unenumerated gums and resins were 74,077 cwt., 264,995*l.*, in 1876; 86,972 cwt., 274,577*l.*, in 1877; 76,152 cwt., 301,858*l.*, in 1878; 82,327 cwt., 344,410*l.*, in 1879; 92,283 cwt., 345,087*l.*, in 1880. The figures for 1880 were made up as follows:—Straits Settlements, 19,225 cwt., 76,721*l.*; Bombay and Sind, 18,364 cwt., 54,073*l.*; British W. Africa, 7750 cwt., 26,078*l.*; Egypt, 7309 cwt., 19,450*l.*; Holland, 6303 cwt., 16,035*l.*; France, 5304 cwt., 17,960*l.*; Turkey, 5258 cwt., 44,420*l.*; Morocco, 5226 cwt., 19,044*l.*; Aden, 4824 cwt., 19,072*l.*; other countries, 12,720 cwt., 52,234*l.* Our exports of unenumerated gums in 1880 were:—17,251 cwt., 83,608*l.*, to United States; 11,830 cwt., 38,647*l.*, Russia; 11,025 cwt., 38,823*l.*, Holland; 8530 cwt., 31,188*l.*, Germany; 4740 cwt., 22,509*l.*, France; 3432 cwt., 10,724*l.*, Belgium; 9888 cwt., 27,823*l.*, other countries; total, 66,696 cwt., 253,322*l.* The imports of unenumerated gums from Portugal were 572 cwt. in 1876, 350 in 1878, 420 in 1880. From Portuguese W. Africa: 516 cwt. in 1876, 3 in 1879, 163 in 1880. From the Philippines: 373 cwt. in 1877, 1766 in 1880. From European Turkey: 773 cwt. in 1877, 1818 in 1878, 1007 in 1880. From Asiatic Turkey: 4532 cwt. in 1876, 13,035 in 1878, 4890 in 1880; Musyna, in 1879, sent 25 tons, value 2750*l.*, to France, and 168 tons, 17,800*l.*, to Turkish ports; Aleppo, in 1880, sent 18 tons, 2880*l.*, to England, 8 tons, 1280*l.*, to France, 2 tons, 320*l.*, to Italy, 4 tons, 640*l.*, to Austria, 8 tons, 640*l.*, to Turkey, 15 tons, 1200*l.*, to Egypt; total, 55 tons, 6960*l.*; Samsoon exported 774 cwt., 6192*l.*, in 1880; Adana exported 1820 bales, 12,487*l.*, in 1878. From Egypt (excluding "arabic"): 3889 cwt. in 1877, 8072 in 1879, 7309 in 1880. From Morocco (excluding "arabic"): 8168 cwt. in 1876, 3763 in 1879, 5231 in 1880; the exports from Mogador in 1880 (including arabic, euphorbium, and sandarach) were:—1427 casks, 12,725*l.*, to Great Britain; 140 casks, 1185*l.*, to France; 10 casks, 70*l.*, to Portugal; 1 cask, 8*l.*, to Spain; total, 4115 *quintals.* From W. Africa: 2911 cwt. in 1876, 629 in 1878, 773 in 1880. From E. Africa: 1181 cwt. in 1876, 381 in 1877, 966 in 1880. From Persia: 639 cwt. in 1876, 2469 in 1877, 362 in 1880; Bushire, in 1879, sent 1200 *rupees*' worth of "Persian gum" to England, and Bahrein sent 50 *rupees*' worth to Koweit, Bussora, and Bagdad. From British W.

Africa: 5675 cwt. in 1476, 4134 in 1878, 7547 in 1880. From Aden: 5001 cwt. in 1877, 9841 in 1880. From Bombay: 16,693 cwt. in 1876, 27,866 in 1877, 19,862 in 1880. From the Straits Settlements (excluding guttapercha and lac): 9832 cwt. in 1877, 7567 in 1879, 19,225 in 1880. From S. Australia: 373 cwt. in 1876, 4442 in 1879, 3908 in 1880. Panama exported 14*l.* worth of "balsam" to the United States in 1879.

Bibliography.—T. Müllner, 'Gewinnung und Verarbeitung des Schwarzföhrenharzes' (Vienna: 1867); O. C. F. Déniau, 'Le Silphium [Asafœtida]' (Paris: 1868); F. A. Flückiger, 'Gummi und Bdellium von Senegal' (Schaffhausen: 1869); de Gomicourt, 'L'Ailanthe globuleux, ou vernis du Japon' (Auch: 1870); J. Collins, 'Report on Caoutchouc' (London: 1872); R. J. Bernardin, 'Classification de 100 Caoutchoucs et Guttaperchas' (Ghent: 1872); J. Wiesner, 'Die Rohstoffe des Pflanzenreiches' (Leipzig: 1873); M. C. Cooke, 'Gums, Resins, Oleo-resins, &c., of India' (London: 1874); G. W. Strettell, 'Caoutchouc from *Chavannesia esculenta*' (Rangoon: 1874); Curie, 'Produits résineux du pin maritime' (Paris: 1874); F. Bouquinat, 'Les arbres résineux' (Chalon-sur-Saône: 1875); C. R. Markham, 'Cultivation of caoutchouc-yielding trees in British India' (Jour. Soc. Arts, Vol. xxiv., No. 1220, London: 1875–6); A. Herlant, 'Produits résineux des Conifères' (Brussels: 1876); J. E. O'Conor, 'Lac: production, manufacture, and trade' (Calcutta: 1876); E. Hirschsohn, 'Galbanum, Ammoniaque, Opopanax et Sagapénum' (Paris, Ghent, Leipzig: 1876); A. W. Miller, 'Mezquite Gum' (Pharm. Jour., Vol. vi. [xxxv.], No. 309, London: 1876); A. Corre, 'The Gums of Senegal' (Pharm. Jour., Vol. vii. [xxxvi.], No. 329, London: 1876–7); R. Cross, 'Report on Indiarubber trees of Para and Ceara, and Balsam of Copaiba' (London: 1877); Croizette Desnoyers, 'Le gemmage du pin maritime' (Paris: 1878); M. Giraud, 'Origin of Tragacanth' (Pharm. Jour., Vol. viii. [xxxvii.], No. 405, London: 1878); F. A. Flückiger, 'Luban mati and Olibanum' (Pharm. Jour., Vol. viii. [xxxvii.], No. 407, London: 1878); J. Morel, 'Resinous Products of the Coniferæ' (Pharm. Jour., Vol. viii. [xxxvii.], Nos. 368, 371, 381, 384, 394, 403, 411, 415, 417, Vol. ix. [xxxviii.], Nos. 451, 453, London: 1877–9); H. Trimen, 'The Plants affording Myrrh' (Pharm. Jour., Vol. ix. [xxxviii.], No. 462, London: 1878–9); G. H. Prochazka and H. Endemann, 'Chicle' (Pharm. Jour., Vol. ix. [xxxviii.], Nos. 469–70, London: 1878–9); Flückiger and Hanbury, 'Pharmacographia' (London: 2nd ed. 1879); R. H. Parker, 'Myrrh: its composition and impurities' (Pharm. Jour., Vol. x. [xxxix.], No. 475, London: 1879); R. Hoffer, 'Kautschuk und Guttapercha' (Vienna, Pest, Leipzig: 1880); R. H. Parker, 'Chian Turpentine' (Pharm. Jour., Vol. x. [xxxix.], No. 521, London: 1880); C. L. Mitchell, 'Gum Hogg' (Pharm. Jour., Vol. xi. [xl.], No. 530, London: 1880); H. T. Geyler, 'Ueber Japanischer Lackbaum' (Frankfurt-a-M.: 1881); G. E. C. Beauvisage, 'Origines Botaniques de la Gutta-percha' (Paris: 1881).

(See Indiarubber Manufactures; Oils [Vegetable Volatile]; Varnish; Wax.)

ROPE (Fr. *Cordage*; Ger., *Tauwerk*).

Of the industries dealing with fibrous materials, rope and twine manufacturing has been the latest to come under the influence of the mechanical inventor. Its comparative insignificance for a long time was its chief protection. Whilst the textile industries offered larger fields and greater rewards to the ingenuity of the schemer, this department was ignored. Rope and twine manufacturing as an industry was scattered all over this country in the towns and villages, but flourished mostly at or in close proximity to our sea-ports, where, for the supply of shipping, there existed the greatest demand for its products. As in every other handicraft, the processes until within a comparatively recent period, were of a rude and primitive character, having been transmitted from one generation to another through centuries, most probably without important modification. With the rise of the modern system of manufacturing, the growth of population, and the enormous development of commerce, our requirements were so largely increased that these primitive methods no longer sufficed to satisfy them. The inventor's aid was therefore called into requisition, and the result has been that, within the past 15–20 years, the ancient methods of manufacture have been quite revolutionized.

The raw materials employed in the manufacture of ropes, cords, and twine, are very various, and include hemp, flax, cotton, jute, manilla-hemp, coir, horse-hair, wool, camel-hair, and other animal fibres. In addition to these, iron, copper and brass-wire are sometimes employed, the first-mentioned metal having come into extensive use. In remote times in this country, the native rushes or *junci* were employed for making ropes, whence the word "junk," worn-out rope. To the preceding, the economical proclivities of the times have added the tows of the various fibres, scutching-waste, jute-cuttings, old ropes, refuse fibres, gunny-bags, sacking, and almost every description of waste from fibrous materials that can be combined by the twisting process into a yarn.

The highest qualities of the various articles are made from the best materials, such as the long line of the hemps and flaxes, and sound cotton. Medium sorts are produced from jute, various coarse fibres, and the tows of hemp and flax. Inferior descriptions are obtained from the wastes and broken-up materials just mentioned. Each of these leading divisions possesses numerous grades, accordingly as the materials employed will permit of being assorted into different qualities.

It is probable that, as the fibrous plants of different countries become better known, numerous additions will be made to the list, as it is certain that for these purposes, there are many quite as suitable as any now in use, almost unknown save to scientific inquirers. The qualities requisite are pliability, softness, smoothness, strength, and a length of staple of from 3 in. upwards.

The word "rope," properly used, implies an article exceeding 1 in. in circumference; smaller descriptions are named "cords," "lines," "twines," "threads," &c., and their constituents, "yarns." After the preparatory stages have been gone through, the product of the first operation, which is spinning, is "yarn." A given number of yarns—more or less, according to the thickness of the article required—are twisted together to form a "strand"; three of these combined by the same means compose a "rope"; whilst a similar union of three ropes constitutes a "cable."

In making cordage of all kinds, the object of twisting the fibres is to obtain increased length. Singular as it may appear, it has been affirmed, and probably with truth, that this twisting of the fibres does not increase the strength, but considerably diminishes it. If a given number of fibres of equal length be placed in parallel order, and their tensile strength be tested, it will be found considerably greater than that of the same fibres twisted into a compact cord. This is because, in the first case, the strain upon each fibre is equal to that upon every other, and the total strength is that of all of the fibres added together. When these fibres are twisted, those forming the external layer, having to wrap round those constituting the core, are strained both in this process and when their tensile power is tested, and are the first to break, thus leading to the fracture of each in detail. From experiments that have been made, it has been found that this loss of strength amounts to 30 per cent. of the strain-bearing power of the untwisted fibres. The object, therefore, being to get continuity of length, all twisting which exceeds that necessary to prevent the fibres slipping over each other when a strain is applied is to be avoided, as entailing a loss of strength.

Hemp (see Fibrous Substances, p. 934), the material of which the best ropes are ordinarily composed, as compared with flax, is much coarser and stronger, but is cultivated and treated in a very similar manner, the processes of retting, breaking, and hackling being like those of flax.

HAND-MADE CORDAGE.—In those establishments where the manufacture of ropes is still carried on by hand, the first operation is "hackling." A certain quantity of hemp is weighed to the hackler, and given proportions of this are combed out at one operation. The hackle or heckle consists of a number of steel pins vertically inserted in a board with their points upward. The fineness of these pins depends upon the character of the work. The operation of hackling differs little from that described in Linen Manufactures (p. 1244), detailing the treatment of flax. Each hackled portion is tied into a bundle, technically called a "strick of hemp." This is then passed to the spinner for making into yarn. The spinning process is conducted in a long covered walk, termed the "rope-walk," which is furnished with the simple means necessary for the conduct of the different operations. The principle end of this walk is usually called the "head" or "fore-end," and the opposite extremity, the "foot" or "back-end." At one end is a spinning-machine, consisting principally of a large wheel, which, by band, friction, or teeth (all are employed), drives a number of small pulleys or "whorls," each carrying a small hook on its axle, that, by the turning of the large wheel, receives a rapid rotary motion. A boy generally turns the wheel, and as many spinners can work from one wheel as there are small whorls driven by its revolution. The spinner, after fastening the strick of hemp round his body, draws out from the front of the bundle the quantity of fibres required to form the size or thickness of the yarn it is desired to make. Bending these fibres in the middle, he passes the bight upon the revolving hook, which instantly twists them, the spinner, at the same moment, beginning to walk backward, and passing more fibres to those which are already being twined. This is done continuously and carefully so as to maintain the evenness and continuity of the thread. In his right hand, the spinner carries a thick piece of woollen cloth, a portion of which he allows to fall over the fore-finger, and with which he grasps the fibres as they are drawn out, and presses them firmly between his two middle fingers. As he steps backward, the driving-wheel continuing its revolution, with his left hand he draws out and regulates the supply of fibre, so as to ensure the yarn being of equal thickness throughout its length. The "walk" may be 200 yd. upwards in length, and the spinner, as the yarn lengthens in his hands, passes it over bearers attached to pillars or the walls of the enclosure. When the length of yarn is completed, it is either passed to one side upon the bearers to await a finishing process, or is wound upon a reel and put aside until wanted.

If it is intended that the ropes shall be tarred, this process takes place at this stage. A number of yarns, 200–300, are laid together in parallel order, and passed through a boiler of hot tar. As they become saturated, the bundle of yarns is drawn through a hole, called a "grip," which has the effect of pressing the tar into the yarn, and removing the superfluous portion. Tarred ropes are more durable than untarred ones, owing to increased power of resisting the decomposing action of water in the alternate immersions or saturations and dryings to which ropes are often subjected in use.

The next operation is the "twisting" of the yarn, whether tarred or untarred, into strands. Rope-walks are usually divided into parts, each fitted with appropriate machinery: the spinning-walk, with its wheels, and the twisting- or laying-walk (sometimes combined in one, sometimes separate, according as the work may be light or heavy), each having its tackle-boards and sledges. At the head of the walk, two stout pieces of timber are inserted vertically in the ground. Across these, is bolted a strong board, which contains three holes corresponding to the number of strands in a rope. This forms the tackle-board. The three holes are in a horizontal line, and are for the reception of winches or forelock-hooks. The proper number of yarns to form the strand having been affixed to these hooks, the opposite extremities are attached to corresponding forelock-hooks in the breast-board of the sledge, a strongly-built frame of wood, constructed so as to be easily loaded with weights according to requirement, and furnished with twisting-hooks similar to those of the tackle-board. The sledge being drawn back, so as to bring the yarn into a tense condition, twisting is commenced both at the forelock-hooks and those of the sledge, the twist of course being in opposite directions. The contraction in length which ensues drags the sledge in towards the fore-end of the walk. When sufficient "hard," as twist is technically called, has been given to the strands, the twisting is complete. The three strands are then attached to the middle hook of the tackle-board, and each strand is laid into one of three grooves of a cone-shaped piece of wood, called a "top," and which will come under notice subsequently. These strands are next twisted together, the "top" receding from the twisting-hook as the rope is formed. This process is called "laying" or "first lay," and consists in combining three strands into a rope, the rope thus made being termed "hawser-laid." In this form, the strands are allotted a sufficient number of threads to give the required thickness to the rope. There is another combination, called the "shroud hawser-laid" rope, or "second lay," in which four strands are twisted round a core-piece placed in the centre to impart greater solidity to the rope. There is also the "third lay," or "cable-laid" rope, in which three ropes, as formed by the first-named process, are twisted or laid together to constitute a cable: a stout strong article formerly in extensive use for ship's purposes, but now mostly superseded by chain cables.

This brief description will sufficiently indicate the handicraft methods of rope-manufacturing, which are still in extensive use in many countries, but are in course of replacement by the introduction of machinery, which will now come under notice.

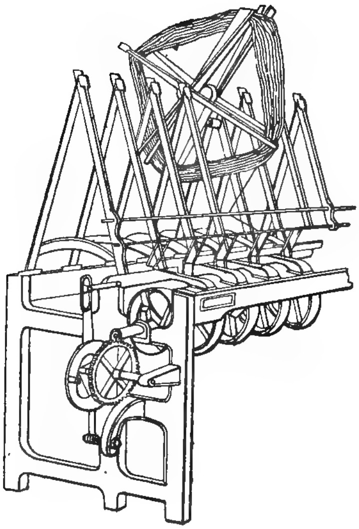
Machine-made Cordage.—The most complete rope- and twine-factories are fitted with every requisite for dealing with the raw material from the commencement, and carrying it through each succeeding stage until it emerges in the finished form, whatever may be required. This of course includes sets of preparatory and spinning machinery, which differ according to the nature of the material to be treated. The best descriptions of yarn are those made from the long fibre or "line" of the raw material, and the machinery employed is denominated "line-machinery," a set of which includes hackling-machines, spreading-frames, first, second, and third drawing-frames, roving-frames, and wet and dry spinning-machines. Every "set" of machines is subject to modification, according to the requirement of the manufacturer. Where a low quality of material is used, there are often only two drawing-frames in the set; but where good yarns are made, three are quite indispensable. For tow and low yarns from waste materials, what is called "tow-machinery" is employed, which, in several of its component parts, differs essentially from a line set.

The roughest and dirtiest qualities of material require some preliminary treatment, the first process being "willowing," to clear away the dirt and earthy matter that may have got intermixed with it. When the fibres are too long to be entrusted with safety to the carding-engine, the material is first passed through a "teazer," by which it is torn and broken down to the necessary dimensions. The teazer is called into requisition when such materials as jute, phormium fibre, some sorts of tow, long hemp which has been damaged, scutching-hemp, and some other sorts, are used. Woven fabrics, such as old canvas, mats, and gunny-bags, are broken up by a ' teazer-card," a combination of the foregoing, and a carding-engine.

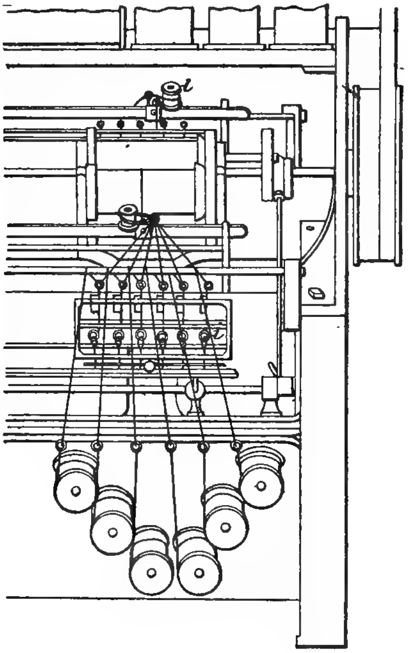
With an average quality of material, however, these processes are not necessary. It is at once passed successively through a "breaker" and 'finisher" card, in which, the carding is completed, the fibres being laid parallel, and delivered in the form of a sliver. A number of these slivers are doubled in the drawing-frame, and attenuated or drawn down to the dimensions of one; this process is repeated in the second drawing-frame, by which it is sought to remove all irregularities. The sliver thus prepared is conveyed to the roving-frame, where further elongation takes place, and a slight amount of twist is imparted to the "rove," as it is called at this stage, in which it is also wound upon bobbins. The latter are then ready for the spinning-frame, in which the rove is further and finally attenuated to the required dimension, and firmly twisted, forming yarn. There are two methods of spinning, dry, and wet: in the latter, the water may be cold or hot, according to the nature of the work. The greater portion of spinning is dry, which enables a far more extensive production to be obtained, the cost of driving being less, and the outlay upon machinery much smaller. Ordinary yarns, and those for heavy twines, are spun on the dry system; fine yarns, on the wet plan with hot water, owing to the fact that hot water to some extent dissolves the natural gum which binds the fibres together, and thus liberating them, enables the yarn to be drawn out much finer, though the loss of its gum diminishes its strength. When it is desired to preserve the highest degree of strength, cold water is used. The coarsest yarns are often spun upon a modified roving frame, called the "Gill spinning frame," by which, one process is obviated, and the cost reduced. This spins coarse yarns, whether composed of line or tow materials.

Hand-spinning has so far been superseded by machinery that a great number of rope- and twine- manufacturers prefer to buy their yarns from spinners, who do not carry the processes farther. When this is the case, the yarn is received in the hank form, and is wound upon bobbins in a hank-winding frame, of which there are several kinds. The hanks are placed on a frame, and the end of the yarn is attached to a bobbin, which is driven by a drum, whose face revolves in contact with the barrel of the bobbin or the yarn upon it as it is filled (Fig. 1186). The machine has a transverse motion, by which the yarn is wound in even layers. These machines are made of various sizes, according to the fineness of the yarns, but average about 20 drums to a machine, which is thus enabled to wind from 20 hanks at once. These hank-winding machines are not required in establishments where the yarn is spun, as then the spinner is enabled to place his spinning-bobbins direct upon the creel of his twisting-frame, by which he saves two processes and two costs—reeling and re-winding.

1186.

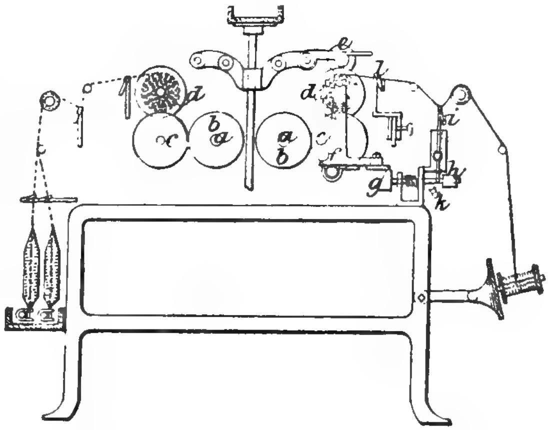


1187.



Winding.—Formerly the threads or yarns contained in the strands were wound by hand into a ball from a creel containing the requisite quantity of yarns, but this system, owing to the irregular draft of the threads by the hand, and the twist imparted by balling, only yielded an indifferent quality of twine. Several machines have been invented to obviate the defects of hand-winding, with more or less success. Fig. 1187 is an illustration of one of the most recent and perfect of doubling-winding-machines, as machines for winding several threads together upon one bobbin are called. It is described by the inventor, T. Unsworth, Manchester, as a direct-acting, draw-bolt, positive stop-motion, doubling-winding-frame. With slight modifications, chiefly in dimension, it can be adapted for working any description of fibre—silk, cotton, wool, flax, jute, or hemp, and in any degree of fineness. It can be constructed to wind any number of threads upon one bobbin: it is usually made for 15–20. A shaft *a* (Fig. 1188) bearing upon the ends of the frame extends throughout its length, and is fitted with friction-drums *b*, and, projecting beyond the frame, also carries the driving-pulleys. Each drum has a similar one *c* adjusted to be driven by the friction of the one first mentioned. The second drum is in contact with and drives the bobbins *d*. Over the bobbin, is placed a porcelain pressure-bowl *e*, which works in contact with the yarn upon the bobbin. Beneath the second drum, and hollowed to fit its periphery, is a brake, into which, by the action of the stop-needle, the drum is made to fall. This drum *c* is fitted upon a lever *f*, the opposite end of which projects towards the front of the machine, extending to and resting upon the draw-bolt *g*—a bar covered with a spiral spring to hold it in position, and which sustains the bolt in contact with the driver drum. The reverse extremity of the draw-bolt has a cross-piece *h* attached, thus forming a representation of the letter ⊥ laid horizontally with the cross-piece outwards. In the oblong frames affixed near the front of the machine, each of which is horizontally divided by a bar through the middle, are inserted the direct-action stop-needles *i*, which constitute the chief feature of the machine. The needles are composed of two parts, looped together (Fig. 1187). On the upper part, is a curl through which the threads pass; the lower part, pendant by the loop from the upper, drops its extremity on the inner side of the cross-piece of the T-shaped draw-bolt *h*, and the outer side of a rocking-bar *k* extending the length of the machine, which is actuated by eccentrics.

1188.



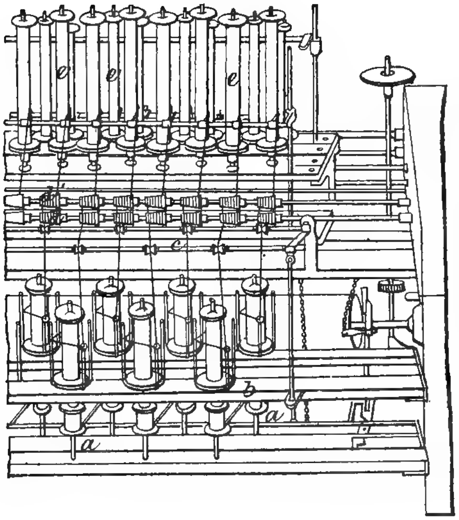
The cops or bobbins having been placed in the creel, the threads from each are conducted upwards through the first eyelets, thence over a glass rod, through the curls of the stop-needles, and around the revolving porcelain bowl or curl *l* of the yarn-guide, whence they pass upon the bobbin. The action of the machine is as follows:—The needle, by means of the thread, is suspended at such a height as to be clear of the rocking-bar; but when the thread sustaining it breaks, it instantly falls, its lower extremity dropping in front of the rocking-bar, which strikes it against the draw-bolt, pushing the latter forward so as to release the end of the lever supporting the second friction-drum, which instantly drops into the half-round break, and at once stops the revolution of the bobbin without friction.

The chief objects sought in doubling-winding are uniformity in the lengths of the threads laid together, equality of tension, and freedom from "single" caused by dropped threads. All these faults are discovered in subsequent processes, showing themselves in "cork-screws" and other defects, which greatly deteriorate the quality. The lengths may vary through irregularity in winding, caused by a varying amount of friction upon the different bobbins, or an uneven deposit of the yarn upon the barrel of the bobbin. But by this machine, both these faults are prevented: the first by the suspension of the stop-needle upon the thread, which takes up any momentary slack; and the second by the threads being passed in a tape-like band over the revolving bowl upon the traverse-rod, which deposits it evenly upon the bobbin, which the pressure-bowl further helps to render firm and level. "Single" is prevented as previously described. The pressure-bowls are made of 3–20 lb. weight, according to the nature of the fibre upon which the machine is to be employed.

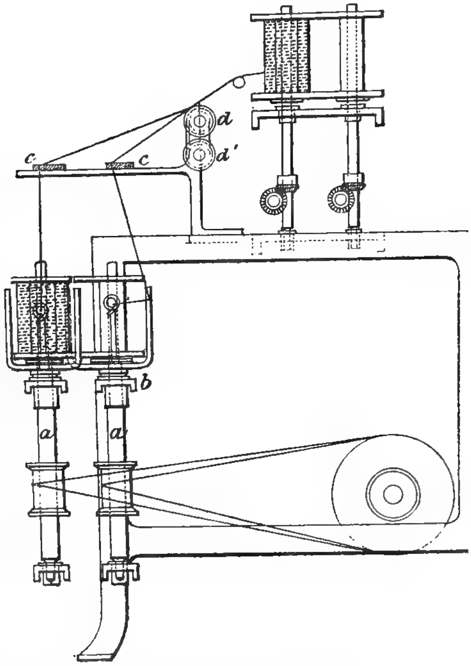
Twisting.—The bobbins containing the threads necessary to form a strand are conveyed to the twisting-machine, an improved form of which is shown in Figs. 1189, 1190. The twisting-spindle *a*, which receives the bobbin from the last-mentioned frame, occupies the ordinary position; but its flier, which has two or four legs as may be required, is inverted, and brought down upon the spindle to near the bolster-rail *b*, resting upon a metallic washer, which carries one of cloth or flannel, by means of which an easy drag of the bobbin is obtained. The inversion and change of position of the flier give increased steadiness to the spindle, especially when running at high velocities, and thus, at less expense in wear and tear, a greater production and superior quality of yarn are obtained. The attainment of high speeds in this machine is greatly facilitated by the bolster-rail not being a traverse-rail as well; all the weight of the yarn, bobbin and flier is concentrated upon the bearing, while the spindle is reduced to the size of the bobbin. The unwinding traverse is obtained by passing the yarn round one leg of the flier.

After leaving the bobbin, the yarn passes over a carrier-rail *c*, and upon the twist-rollers intermediate between the delivery- and the taking-up-rollers. The twist-rollers *d d'* are conical grooved pulleys placed upon parallel horizontal shafts, one function of the first row being to draw the yarn from the bobbins, whilst the revolving spindle puts in the twist. The yarn passes upon one of the smallest grooves of the cone *d*, and over a larger one in the cone *d'*, which stretches the strand and lays the yarn well together before it passes upon the taking-up-bobbin *e*. The last-mentioned bobbin can be made of any required dimension, as, its only function being to take up the yarn when twisted, weight is no objection. In the sectional view, the twist-rollers are shown with an alternative arrangement.

1189.



1190.



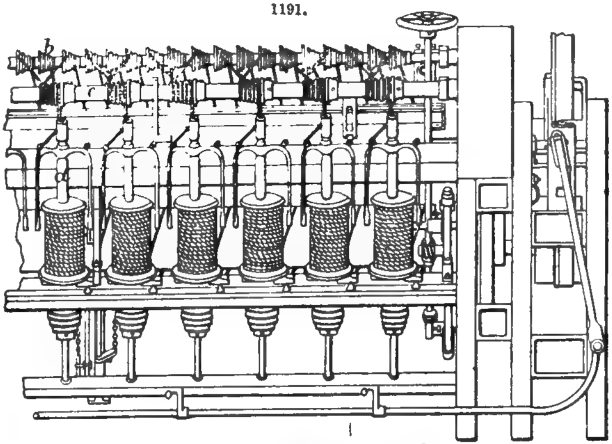
This machine, one of whose novelties lies in its being an "upward twister," has a great productive power. One of 200 spindles will turn off 2400 lb. a week of 3-fold 8's cotton, 9 turns an in., which is $\frac{1}{3}$ more than can be obtained from ordinary machines. One girl can superintend the machine, creeling and doffing without assistance. Owing to the employment of large winding and taking-up-bobbins, a greater length of yarn can be produced without a knot; and through the stretching on the cones, the twisted strand is made round, firm, and full. The cost of warp-winding is also saved, as the machine winds the yarn upon large warping-bobbins during the operation of twisting; less space and power are also needed.

For heavy fibres, as flax, hemp, and jute, strong machines are constructed, which deal with them as efficiently as the light ones do with wool, silk, or cotton. The winding or twisting-bobbin for heavy fibres may be made up to 8-in. lift and 5-in. diam., capable of holding 3½ lb. of yarn, and, in these dimensions, can be worked up to 2000 rev. a minute. For "once-twisted" or "hung-on" twines, as the Scotch call them, the machine possesses great advantages.

In the manufacture of cable-laid twines or cords, the following machine is employed in several large establishments (Figs. 1191, 1192, 1193). The bobbins from the doubling-winding machine, Fig. 1187, are brought to this machine, and placed upon the back spindles containing the inverted fliers *a*, Fig. 1193, the strands being conducted over the guide-rails, to the back twist-rollers, which draw the yarn from the bobbins as in Fig. 1189, whilst the revolving spindles similarly put in the twist. Each strand is placed upon the smallest groove of the cone-shaped rollers *b*, then around the others, to the top one of largest diameter, by which means it is stretched the difference between the largest and smallest diameter, which imparts firmness and great solidity to the strand. This constitutes the first twist or lay; the second twist or cabling is imparted by passing three strands from three of the cone-rollers just mentioned over the cone-rollers *c* on the front or second shaft, by which they are laid together, and passing round grooves as before, are again stretched, delivered to the topping-motion, twisted by the powerful spindle and flier *d*, and wound upon large bobbins, often of 8-in. traverse by 6½-in. head. This machine contains two driving-cylinders, one each for the front and back, so that the amount of either first or second twist can be regulated with nicety and ease.

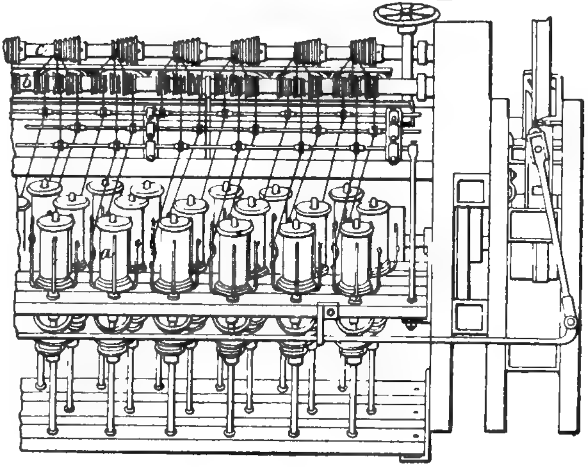
One of these machines 11½ by 5½ ft., containing 30 back and 10 front or finishing spindles, is capable of yielding a production of 1500 lb. of 1-lea laid twine a week, one girl superintending. It makes all kinds of twine, from fine to coarse, and hard or soft, according to requirement; and includes such diverse articles as spindle-bandings, piping-cord, heavy fishing-net twines, fishing-lines, loom-cords, hair-cords, three-cord cabled twine, trimmings, and fancy cords of all descriptions.

1191.



In bandings for spindle-driving purposes, the stretching operation upon the cone and grooved rollers is exceedingly valuable, as when the bands are put to use, they never become slack through stretching, and thus enable far better yarn to be produced than when banding made on the old process is employed.

At the Centennial Exhibition, held in Philadelphia, the series of machines of which these form a portion secured to the patentee, Thos. Unsworth, medal, diploma, and certificates for originality, perfection and utility, combined with fitness for purpose intended, quality of products, and economy of working.

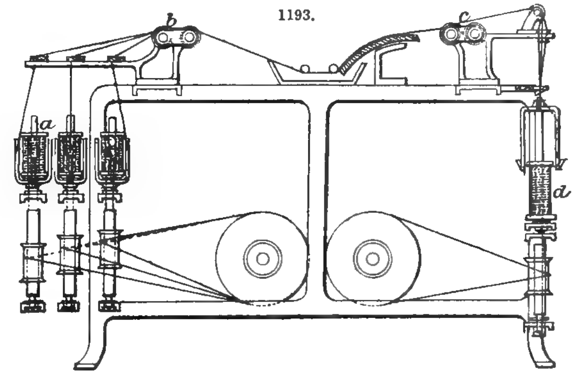


1192.

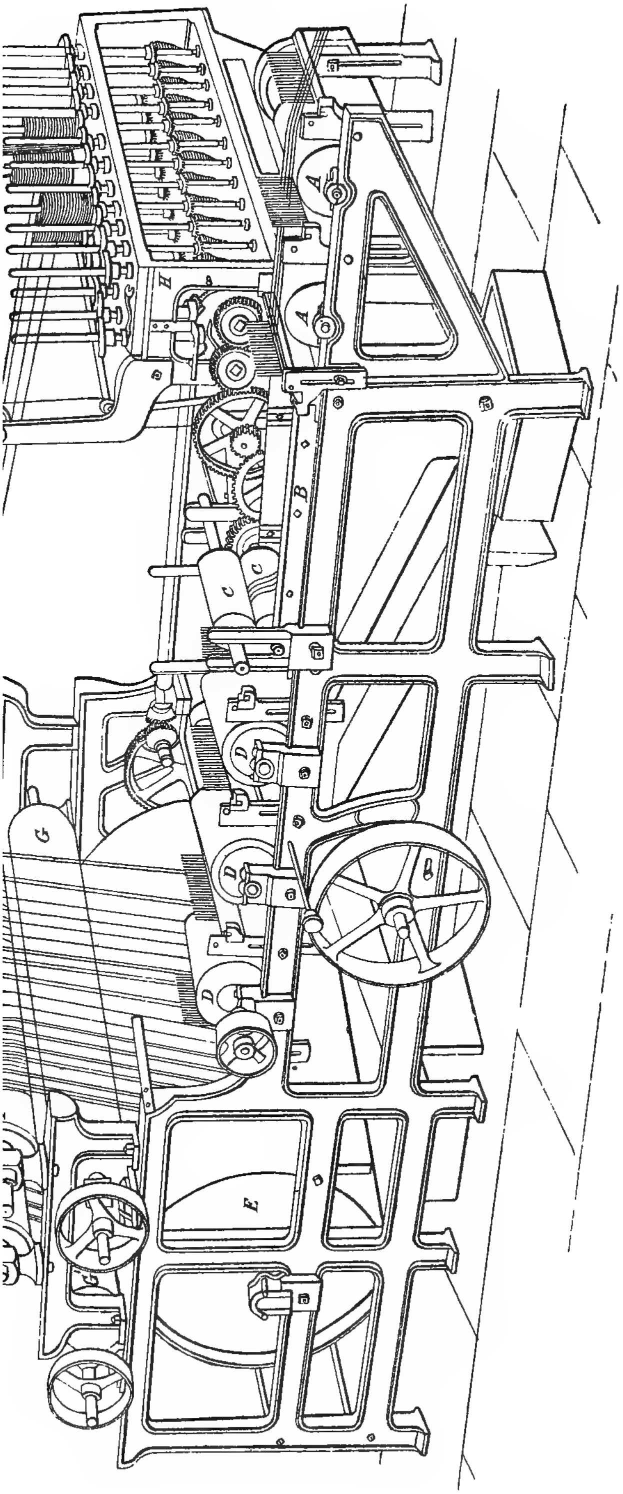
There are several other varieties of winding, twisting, and cabling-machines of considerable merit, but which call for no special notice here.

Singeing.—Twines made from harsh or intractable materials require to be singed before sizing and polishing, which are the finishing processes of this class of articles. Singeing-machines are usually constructed in the form of a winding-machine with about twelve spindles at back and front, the latter drawing the yarn or twine through a jet of flame obtained from a combination of gas and atmospheric air. Sometimes other means are employed to obtain a flame, such as oil-lamps.

1193.



Sizing, Polishing, and Drying.—The operations of sizing, polishing, and drying are generally included in one machine, though, by the older processes, they constituted three distinct operations. Fig. 1194 represents a sizing-, polishing-, and drying-machine, as constructed by Thos. Barraclough,


A
A
H
G
B
C
C
D
D
D
G
E
G

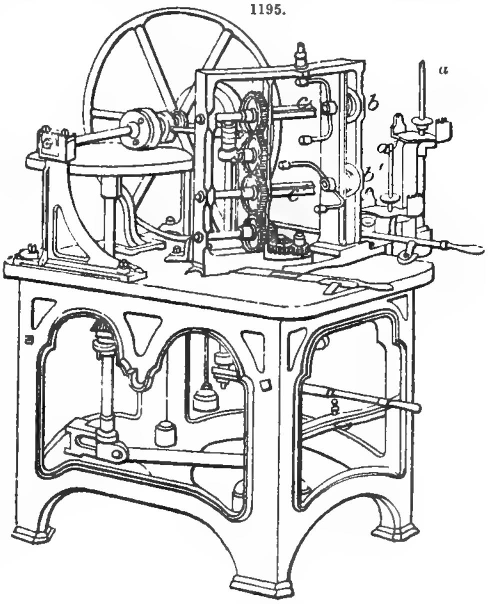
Manchester, who is also the maker of the remainder of the machinery subsequently illustrated in this article, except when otherwise stated. This machine is generally constructed of such a capacity as to take 24 twines at once. The filled bobbins from the twisting-frame, Fig. 1189, are placed in a creel in front of the sizing-machine, and the twines are conducted in parallel order over the carding-rollers A, which are covered with card clothing of suitable strength, and which, revolving at a high speed, brush off the woody portions of the plant, shive, boon, and lumps that may have remained through the preparing stages, leaving the twines smooth and clean. The twines are kept apart by the three sets of vertical guide-wires, from the third of which they pass into the sizing-trough B, a copper or iron tank containing steam-heated size, composed of flour or farina, glue, animal gelatine, or other materials, and brought to the required consistency by means of water. Hot size is indispensable to a satisfactory result; cold size merely coats the surface, and would soon break and rub off in wear. In the spinning and twisting processes, it is impossible to combine the fibres into a *solid* thread; in the interstices, is a considerable quantity of atmospheric air, which, on the twines passing through the boiling size, is expanded by the heat, and escapes, the space it occupied being instantly filled by the hot size, thus ensuring a comparatively solid cord. Emerging from the size, the twines pass between two pressing-rollers C, which squeeze out the superfluous size, and return it to the tank. Guide-wires capable of being depressed, so as to make the twines cover a greater or less portion of the periphery of the rollers D, which are covered with coir, conduct them over these in succession, by which the loose fibre is rubbed in, and a smooth surface is ensured. After leaving these rollers, the twines pass upon the large cylinder E (which is heated by steam), and helically around it several times, being directed by two guide-rollers F F′, so as to pass off the cylinder at the opposite side from that on which they enter. The drying is also facilitated by the circulation of air in the helical interstices formed by the presence of the twines. The polishing process is continued by the action of two rubbing-rollers G G′, extending across the length of the cylinder, and similarly covered with coir. One of these revolves against the outside of the set of twines during the passage round the drying-cylinder, and the second polishes the under surface revolving in the space formed by one of the angle rollers, thus completing the polishing operation. The twines, on leaving the rollers, are conducted over two carriers to the winding-frame H at the front, which contains an equivalent number of spindles, and winds the twines upon the bobbins with which they are filled. In the figure, only four threads are shown, for the sake of clearness.

The composition of the size used is of considerable importance, when the best result is desired. An authoritative writer has recently given the following as a good practical recipe:—36 lb. wheat-flour is mixed with cold water until a paste is formed; 22 gal. of water is put to boil, and 2–3 lb. of cow-horn glue, Irish moss, or animal gelatine, 5 lb. of alum, and 6 lb. of tallow are added; when boiling, the paste is added, and the mixture is boiled until it thickens, when it is ready for use in the machines. This is a good compound for medium and heavy twines; for fine twines, the alum, and half of the tallow, is usually omitted.

The sizing-machines are made in two sizes; in the smaller, the drying-cylinder is 72 in. across the face, and 30 in. diam., and will size 1000–1800 lb. of twine in a week of 60 hours. This is the most suitable for light descriptions of twines, the drying of which is not difficult. The larger one has a drying-cylinder 96 in. long, and 36 in. diam., and will size, polish, and dry 1800–3000 lb. in 60 hours. This is employed for heavier twines; but for the heaviest, it is necessary to have two cylinders, in order to dry them thoroughly.

Sizing is sometimes regarded as a needless and expensive process, but the weight imparted to the twine is ample compensation for the expense (yarn being generally sold by weight), while the improvement in the quality is undoubted.

1195.



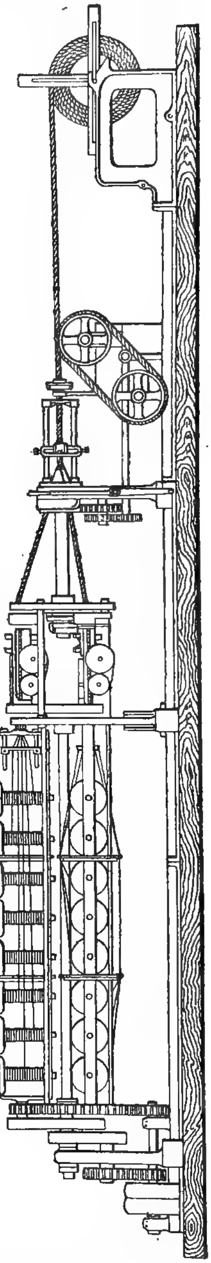
Balling.—Balling is the last and finishing process in the manufacture of twine. Two bobbins of polished twine are placed upon the vertical spindles *a a′*, in Fig. 1195. The twines are taken from these, passed through the necks of the fliers *b b′*, and down one leg of each, whence it is wound upon the horizontal spindles *c c′*, which, by other appliances, have imparted to them the peculiar automatic movements required to form the twine into balls. As the balls attain the required weight, they are doffed and finished by the attendant girl lapping the twine several times very firmly round the middle. In balling light twines, the double machine is usually employed; for heavy descriptions, the single one, making only one ball at a time. They are fitted to be worked by manual or steam power, as may be most convenient.

Ropes.—The section now calling for attention is the manufacture of fibrous ropes; these, as explained previously, are technically known as hawser-, shroud-, and cable-laid, besides flat ropes formed by placing several ropes parallel to each other, and uniting them by oblique stitches, thereby producing a flat band.

In manufacturing these articles, the raw material is treated as previously described in the preparatory stages, spun into yarn, a number of yarns twisted into strands, these into ropes, and the latter into cables. In these processes, it is invariably the method to twist the article in the direction opposite that of the preceding stage. Thus, supposing the yarn is spun with a right-hand twist, the strands into which this enters will be twisted to the left, and the rope into which these are combined must be twisted to the right, or in the same direction as the yarn, and so on with succeeding combinations. This is requisite to prevent or overcome the tendency that would otherwise exist to run into loops or kinks whenever the ropes were brought into use.

Necessarily the machinery for performing this heavy work differs considerably from that previously described, inasmuch as a machine seldom makes more than one article at a time. Again, to avoid excessive complexity of the machine, and the consequent liability to derangement, it is usually found preferable to employ machines for each operation, instead of combining all in one. Especially is this the case in the heavier classes of ropes and cables. In the lighter articles, compound machines are frequently used. These are of two kinds, the vertical and horizontal, the former being employed in the manufacture of long ropes, and the latter generally of shorter lengths.

Laying.—A small horizontal compound rope-laying machine is shown in Fig. 1196. The largest rope of three strands that could be made on this machine would be one of 24 yarns—8 to each strand. It will serve to show the principle on which larger ones are constructed. By means of change-wheels, 3-strand ropes of smaller dimensions can be made upon it, containing 7, 6, 5, 4, 3, and 2 yarns to each strand, the ropes of course being a multiple of those figures by three. The machine has three fliers, each capable of containing 8 bobbins filled with yarn, which are placed in a creel inside the flier, and so arranged as to deliver their contents easily to the draught of the machine. The yarns are conducted through the trunnion of each flier, along the side, through the corresponding trunnion, and upon the three topping-motions. The revolutions of the fliers twist the yarns into strands, which are drawn forward by the topping-motions. The latter revolve with the fliers, and are furnished with grooved draw-rolls actuated by gearing. The strands pass upon and around these grooved draw-rolls, which, being coned, stretch and solidify them before they pass from the stranding part of the machine, and are combined into a rope in the front portion, as shown in the illustration, by their passage through machinery similar to that which formed the strand. The finished rope is wound upon a barrel driven by a differential gearing, in even layers, and when completed, is easily removed by doffing, the barrel being collapsible; the machine is thus ready for work again in 2–3 minutes.

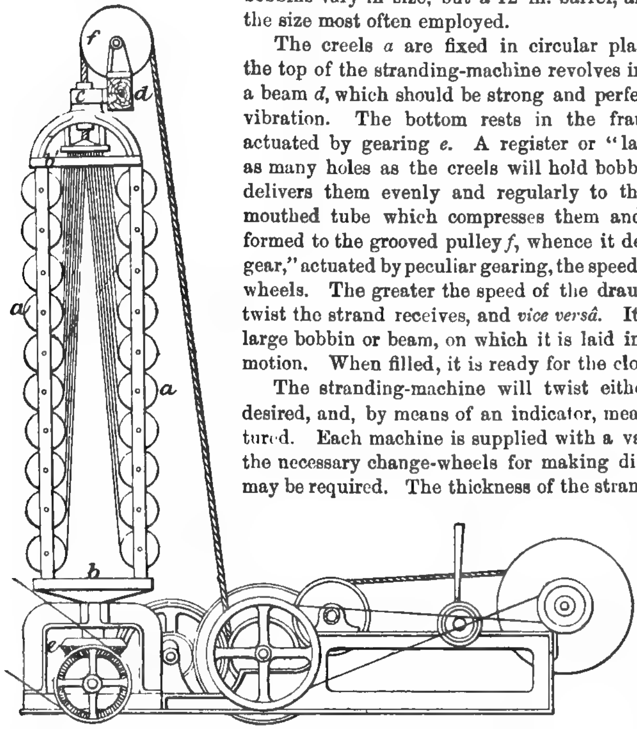


1196.

As will be seen, the machine is compact, simple, efficient, and of great productive capacity, being capable of making 1000–1600 fathoms of rope a day, according to the size, twist and other circumstances that usually affect production. It is made in various sizes, to suit different requirements; when larger ropes are intended to be made, say up to 60 threads, the form is considerably modified. In both sorts, the sizes of the ropes can be altered by the use of change-wheels.

When the manufacture is more varied, it is usual to employ single machines, performing only one operation. The first of these is the stranding-machine, which may be either vertical or horizontal. Fig. 1197 represents a vertical machine, technically called a "stranding-drum." It consists of 2 vertical bobbin-frames; others contain more—4, 5, and up to 10. These creels may be made for any required number of bobbins, and usually contain 4–12. The bobbins vary in size, but a 12-in. barrel, and 12-in. diam. of head, is the size most often employed.

1197.



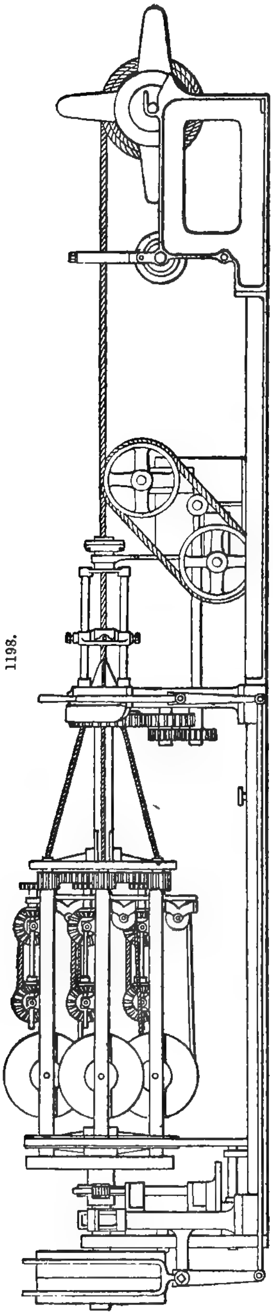
The creels *a* are fixed in circular plates *b b'* at top and bottom; the top of the stranding-machine revolves in an iron bracket *c*, fixed to a beam *d*, which should be strong and perfectly firm, so as to prevent vibration. The bottom rests in the framework, the whole being actuated by gearing *e*. A register or "lay" -plate, perforated with as many holes as the creels will hold bobbins, receives the yarns, and delivers them evenly and regularly to the "stranding-die," a bell-mouthed tube which compresses them and delivers the strand thus formed to the grooved pulley *f*, whence it descends to the "drawing-off gear," actuated by peculiar gearing, the speed being regulated by change-wheels. The greater the speed of the draught, the less the amount of twist the strand receives, and *vice versâ*. It is next conducted upon a large bobbin or beam, on which it is laid in even layers by a traverse-motion. When filled, it is ready for the closing-machine.

The stranding-machine will twist either to the right or left, as desired, and, by means of an indicator, measures the length manufactured. Each machine is supplied with a variety of strand-tubes, and the necessary change-wheels for making different sizes of strands, as may be required. The thickness of the strand is varied by increasing or diminishing the number of yarns contained therein, and also by changing the size or fineness. The machine should be strong, and carefully fixed, in order to produce good work, with an economical expenditure of power. The top of the machine generally extends into the floor above its base, in order to facilitate creeling operations; a platform is also used for the same purpose.

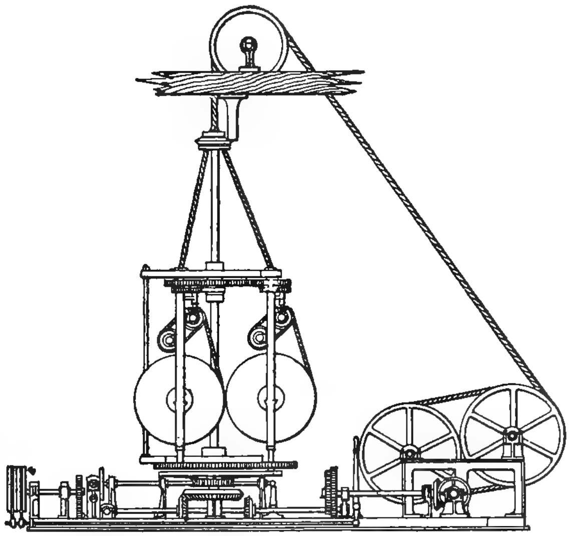
Another form of the stranding-machine—the horizontal,—which possesses several advantages in the facility with which it can be worked, has of late years been coming into general use. It possesses a fixed creel, in which the bobbins can be renewed without stopping the frame, and may be varied in number to any extent. Its production is much greater, it being capable of running at a much higher speed; and the strand-tube, being fixed in an iron box, can be heated either by gas or steam, which polishes the strand to a high degree, and facilitates the process of tubing "hard."

Closing.—The hemp-rope closing-machine, which receives the strands from the former, and "lays" them into a rope, is also made in two forms, the vertical and horizontal. In the latter, Fig. 1198, the construction does not differ materially from that of the horizontal compound rope-laying machine, Fig. 1196, except in its greater simplicity, owing to having fewer operations to perform. The vertical closing-machine, Fig. 1199, has a strong cast-iron frame, and three or four cast-iron frames or creels for the reception of the large cast-iron strand-bobbins, containing the strand manufactured on the stranding-machine. These are caused to revolve by means of suitable gearing, both on their own axis and around the central vertical shaft, the top of which is secured to a strong beam in the building. This action causes the strands to come together, and close at the top of the machine, after which, the rope passes over a sheave or pulley, then down through the drawing-off gear, and upon the coiling-reel, which portion, omitted from the illustration, is made adjustable both in width and diameter, to suit the various sizes of coils required to be made.

These machines are also constructed in various sizes to suit requirements, and have several attachments, not shown in the illustration, such as a regulating drag-gear for delivering the strands at a uniform rate, which is of the greatest importance in securing a well-made rope. The large machines possess in addition a "tempering-motion," the purpose of which is to impart, as may be required, more or less twist to the strands when being laid into ropes. Ropes, according to the uses for which they are intended, require a greater or less amount of twist, and this can be exactly regulated by the "hardening" or "softening" process at the time of closing. It is usual, therefore, for every closing-machine to possess a tempering-motion, without which, it would be incomplete. The machine is made so that its parts will revolve in either direction, so as to make a rope with either a right- or left-hand twist. In the manufacture of shroud-laid ropes, in addition to the four creels or frames for the strand-bobbins, another is required for the core-piece, which is drawn off at the speed at which the rope is laid. Before coming together, the strands have to pass over a "top," the object of which is to deliver them at exactly the same angle and distance, one from the other. These tops are either of wood or iron, but the former are mostly preferred, because, wood being a better non-conductor, the heat generated by the frictional passage of the strand smoothes and polishes it far better than in an iron top, where the heat is dispersed by radiation.



1198.



1199.

Each machine is capable of making a considerable variety of sizes of ropes, varying in the degree of lay or twist, which is accomplished by altering the speed of the drawing-off motion, by means of change-wheels. Similar means are also provided for varying the drag- and tempering-motions, according to requirement.

The various machines, whether vertical or horizontal, required in the processes of stranding and closing are always worked in sets, which generally include two stranding- and one closing-machine to a set, though sometimes three of the former and two of the latter are wrought together, forming what is called a double set.

The standard sizes of the machines—at least of those under description—are indicated by letters, and are as follows:—

Set	E.	horizontal,	makes ropes	up to	1¼	in. circum.
,,	F.	,,	,,	,,	2½	,, ,,
,,	G.	,,	,,	,,	4	,, ,,
,,	H.	vertical	,,	,,	4	,, ,,
,,	I.	,,	,,	,,	6	,, ,,
,,	J.	,,	,,	,,	10	,, ,,

These sizes are based on a length of 120 fathoms in each coil. Where shorter coils will suffice, each set will produce thicker ropes. Their capacity of production is governed by that of the closing-machine, which can always be ascertained by multiplying the length in in. of the turns or twist in the sample, by the number of revolutions the closing-machine is making a minute, and the product will be the number of in. that will be made in the same time. A percentage, which experience will soon dictate, must be deducted from this for stoppages, the remainder being a practical result.

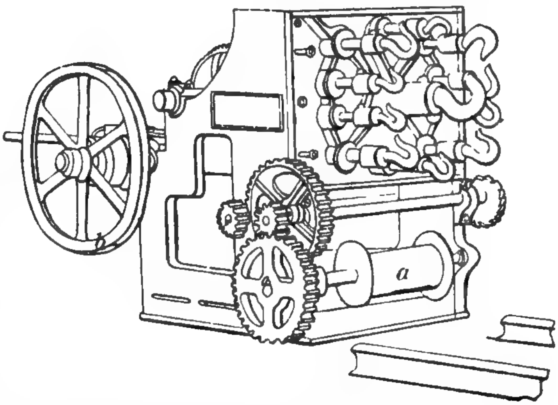
The closing-machines of the different sets make the following revolutions a minute:—E, 130; F, 100; G, 70; H, 60; I, 50; and J, 30.

One man usually superintends a set of machines, taking charge of the closing-machine himself and having assistant boys or girls at the stranding-machines.

The preceding account shows the extent to which the rope-making industry has been revolutionized by the invention of machinery, in comparatively recent years. But even this does not exhibit the full extent of the changes that have been wrought. The old system of making ropes, as previously described, in long rope-walks by machines working in pairs still survives, and in fact, remains the most widely in use. The machines employed, in what may be termed the more ancient form of rope-making establishments, have also been greatly modified and improved, whilst their general outline and method of operation remain comparatively the same. Having already described the former, a brief account only will be necessary of the improvements recently introduced.

The "fore-board" has given place to the "foreturn-machine," Fig. 1200, and the "sledge" to the "traveller," Fig. 1201. In the best-furnished rope-walks, as distinguished from rope-factories, these machines are now generally found. They are used for both the stranding and laying processes.

1200.



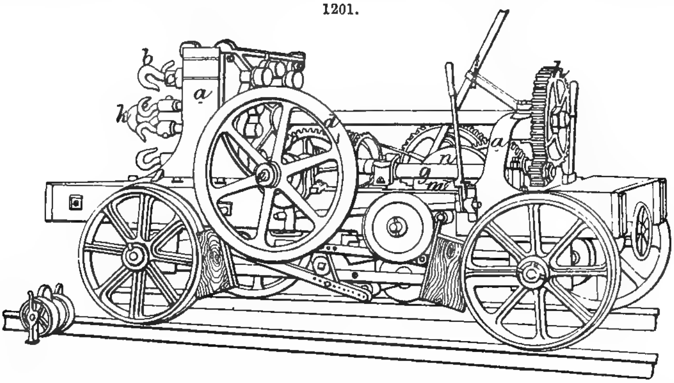
The yarns from which the strands are formed are contained on bobbins placed in the "bobbin-bank" or creel, generally a V-shaped frame with the apex directed towards the rear of the foreturn-machine, to which the yarn is delivered. These creels may, however, be of different forms, according to convenience or requirement, keeping in view the necessity of maintaining the bobbins in a compact arrangement, and enabling them to be easily accessible for the purposes of renewal when their contents are exhausted, and piecing or splicing when the yarn breaks, or faults occur. As these creels require to contain 100–400 bobbins, the importance of these considerations will be obvious.

After leaving the creel, the yarns are conducted through a register-grid—a frame containing a number of vertical round-iron rods, transversely crossed by others, thus forming square interstices, each thread having its separate square. This grid is for the purpose of conducting the yarns in parallel order to the register-plate—a cast-iron plate drilled with round holes arranged in concentric circles, through which the yarns are passed in such a manner as to dispose themselves in passing therefrom in a compact form round one central thread, which thus forms a core. The diameters of the register-plate circles are relatively such as to allow the threads in each circle to arrange themselves at the best ascertained angle, in order to compose a solid strand, and receive the general twist necessary to form it. Passing through the register-plate, all the yarns are next conducted to a strand-tube—a bell-mouthed, slightly tapering, iron tube, which usually passes through a steam-chest, by which means it is heated, to prevent ropes made of tarred yarns sticking fast, in which case they would have to be cut out, thus occasioning waste, defective work, expense, and inconvenience.

The yarns from the "bobbin-banks" are divided so as to form as many strands as are required for the rope to be manufactured. One register-grid suffices for all, whilst an assortment of register-plates is usually required: one for single strands of large diam., having only one series of circles; one for 3 strands with 3 series of circles; one for 6 and one for 12 strands. Each strand has a separate tube. Large strands are usually made singly, but those of moderate dimensions are made 3–12 at a time.

After passing the strand-tube, the yarns for each strand are immediately attached to the hooks of the traveller. The "traveller," Fig. 1201, consists of a powerful iron frame *a a*, in which are mounted a series of wrought-iron hooks *b*, attached to the ends of steel spindles *c*, driven by means of appropriate gearing, the speed at which they revolve being regulated by change-wheels. By means of clutches the direction of their revolution can easily be reversed. Motion is communicated to the traveller by means of an endless driving-rope, which extends from one end of the rope-walk to the other, and passes round the grooved pulley *d* on the shaft *e;* this through the bevel-gearing *f*, actuates the shaft *g*, which again, through the gearing *h* and shaft *i*, revolves the large central hook *k* in the traveller-breast. The shaft *e*, through suitable means, also actuates the shaft *m*, carrying the sheave or grooved wheel *n*, round which, passes a ground rope or chain, which is also attached to the "foreturn" machine, and extends the length of the rope-walk. The whole of this machinery is mounted on a stoutly-made carriage, composed of very strong materials, having powerful brakes, and running upon a rail or tram-car.

1201.



Assuming that it is a 3-strand hawser which is being made, the three sets of yarns, on leaving the strand-tubes, are attached to three hooks of the traveller. The endless rope passing round the grooved wheel *d* actuates the different parts, including the ground rope sheave *n*, the revolution of which causes the "traveller" to run down the walk, drawing the strand-yarns with it through the tubes, which, at the same time, are being twisted by the revolving hooks on the traveller to which they are attached. The strands, as they come from the hot tubes, are quite smooth, round, and polished.

It is now that the "foreturn" is required. This machine, Fig. 1200, is a strong massive frame, mounted with a series of revolving hooks, corresponding to those of the traveller, and actuated in a similar manner. It also possesses a winch *a*, for tightening the ground rope or chain. It receives its motion, like the traveller, from the endless rope or chain that passes over the grooved wheel *b*. This endless rope is the means by which motion is transmitted from a large grooved pulley on the main line-shaft of the works, and which is ordinarily placed under ground. A friction-box is connected with it, in order to ease the starting of the rope-laying machinery.

In order to form the three strands made on the traveller into a rope, their ends are cut near the "foreturn," and attached to three of its hooks, corresponding to those of the traveller. The latter are then made to revolve, in order to "temper," or put into the strands just the amount of twist required. The ends of the strands attached to the three hooks of the traveller are then transferred to one hook: its centre hook, if the rope to be laid is a heavy one. The "top," or longitudinally-grooved cone of wood, is then inserted between the three strands, with its smaller end towards the traveller, and the process of laying is commenced. The top is usually mounted on a small bogie or carriage, placed on the rails on the front of the traveller; and as the twist is put in by the central hook of the traveller in its revolution, the bogie starts away from it, and travels slowly towards the foreturn-machine at the head of the walk, being impelled by the closing of the strands. The rope is twisted in a direction opposite to that of the twist of the strands, but the quantity of the latter is preserved by the continued revolution of the hooks of the foreturn, to which their opposite ends are attached, and which revolve so as to give compensation for the twist being taken out by the traveller. A looped rope made of hair or coir is placed upon the newly-formed rope, and attached to the bogie; this acts as a polisher, smoothing and laying the fibres.

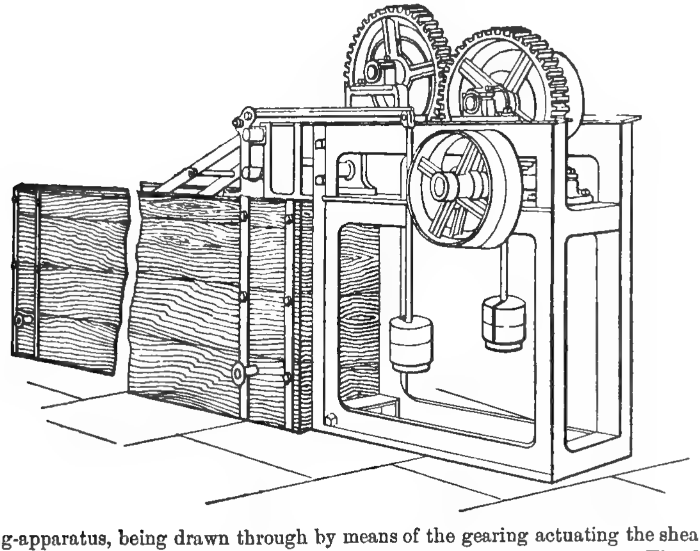
As the twist is being put into the rope, the length is greatly shortened, which draws the traveller up the walk. In order, however, to stretch the rope thoroughly, this draught is resisted as much as possible by the application of powerful brakes to every wheel. When the bogie carrying the top has reached the head of the walk, the rope is finished, and is coiled by power on an adjustable coiling-machine, which can be altered to make any size of coil. The traveller is brought up the walk to the foreturn by means of a brake, which prevents the revolution of the first motion shaft, and the rope, gripping the wheel, causes the traveller to run up the walk at the same rate as the driving-rope.

Both the machines here described are made in a great variety of sizes, and with different numbers of hooks, according to special requirement. Their capacity is very wide, as they will make ropes from the smallest sizes up to 24 in. in circumference. In order to be of the greatest use, they require a full complement of change-wheels and strand-tubes. Sometimes a foreturn will have two travellers, one light and one heavy. When one is in use, the other is run into a siding, or on to an extension of the line beyond the requirement of that in use.

The selection of the factory or walk system of manufacture will generally be decided by the special circumstances of the case, as each has its advantages and disadvantages. The factory or "house" machines, as they are called, are said to be capable of turning off more rope of a better quality, and at less cost for wages and driving-power, than the "walk" machines, though this is a disputed point. They need much less space for their operations, no "walk" and long shed being required. But the machines are numerous and expensive, where a full equipment is necessary, the first outlay and cost of maintenance being greater than when the foreturn and traveller are the chief machines employed. The latter are the simplest, and, where land and labour are cheap, may in some cases be the most advantageous.

The greatest proportion of ropes manufactured are made from tarred yarns. There are two methods of tarring in use: in one, the yarns are tarred singly; in the other, by the "haul." Yarns are tarred singly by arranging a number of large bobbins, usually about 16, on which the untarred yarns are wound, in a creel in front of a double-cased copper steam-vat, in which the tar is kept boiling by means of steam circulating in the cavity. In the pan, a copper or brass roller is adjusted, partly immersed in the tar. Over this roller, the yarns are conducted, and as they pass in contact with it, receive some of the boiling tar, which it brings up in its revolution. The yarns are next drawn along a copper trough, in which are placed hide ropes twisted tightly round them, whose function it is to equally distribute the tar, and, by friction, to lay the fibres, and polish the yarn. Leaving the trough, they are wound upon a large reel, and formed into a haul. In tarring in the haul, the yarns are wound upon a large reel, or warping-mill, in a helical form by a traversing motion, before being subjected to the tar. When the first layer is complete, the threads are passed round a pin or peg, and the motion of the reel is reversed until a second layer is completed. These operations are continued until a warp containing 200–400 threads is made, which is then wound off, and coiled on a revolving plate or iron dish upon a bogie, which is made to revolve for the purpose of imparting to the warp a few turns of twist, to prevent the entanglement of the threads in passing through the subsequent processes and during mellowing. The warp is then taken to the tarring-machine, Fig. 1202, consisting of a large trough or cistern, in which the tar is kept at boiling heat by means of coils of copper steam-piping. The yarn or warp is conducted through the boiling tar, and the pressing-apparatus, being drawn through by means of the gearing actuating the sheaves, around which it is twice passed to prevent slipping, and is then coiled for the store. The difference in these processes is not very material: in the first case, the yarns are tarred before they are made into a warp; in the second, after that operation. In tarring singly, the yarns are warped as they emerge from the tar-pan.

1202.



When the tarring process has been completed, the "hauls" or tarred warps are conveyed into the store, in order to be mellowed, which is simply allowing the tar to penetrate the fibres. The time for this varies according to the quality of the work for which they are intended. Two months is stated to be the shortest time in which this can be accomplished; it is done much better when 6–8 months are devoted to it. In the Royal dockyards, it is customary to allow 12–15 months for the process. The tar used should be clear and of a light colour, in order to impart the best appearance. Contact with iron, when it is fluid, darkens and discolours it, and this should therefore be carefully avoided.

When the tarred yarns are required for use, they are brought from the mellowing-store; the warps are wound upon the reel; the threads are separated, and wound upon bobbins from the reel, thus reversing the previous operations; and the bobbins are conveyed to the stranding-machines to pass through the processes previously described.

Exports.—Our exports of cordage, cables, and ropes of hemp and similar material in 1880 were to:—Australia, 16,665 cwt., 54,155*l.*; British N. America, 16,264 cwt., 34,766*l.*; British W. Indies and British Guiana, 8886 cwt., 18,662*l.*; Brazil, 8409 cwt., 23,237*l.*; British S. Africa, 7074 cwt., 17,767*l.*; Argentine Republic, 6378 cwt., 11,487*l.*; Germany, 5130 cwt., 12,823*l.*; France, 4027 cwt., 8942*l.*; Sweden and Norway, 3615 cwt., 10,272*l.*; Bombay and Sind, 3589 cwt., 8963*l.*; Chili, 3356 cwt., 7564*l.*; Peru, 2767 cwt., 5355*l.*; Italy, 2531 cwt., 5696*l.*; Japan, 2399 cwt., 4944*l.*; United States, 2018 cwt., 4169*l.*; Bengal and Burma, 1927 cwt., 7642*l.*; British W. Africa, 1270 cwt., 4214*l.*; Channel Islands, 1048 cwt., 6000*l.*; other countries, 20,964 cwt., 48,949*l.*; total, 118,307 cwt., 295,607*l.* R. M.

(See Fibrous Substances.)

SALT (Fr., *Sel*; Ger., *Salz, Chlornatrium*).—Formula, NaCl; hardness, 2·5; sp. gr., 2·1–2·57.

If we consider the natural products of the earth in their relative economic importance, salt, one of the most abundant and universally diffused, commends itself pre-eminently to our notice. Yet comparatively little has been written concerning it, and the industry, one of the most important we possess, may be said, with the exception of a few trifling innovations, to be practically in the same position as it was 50 or 100 years ago.

Common salt (sodium chloride) may be directly produced by the combination of chlorine with sodium. It has been stated that sodium takes fire when immersed in chlorine gas; but Wanklyn has shown that, unless some moisture be present, such is not the case, and it is certain that metallic sodium remains bright for some time, even when immersed in liquefied chlorine anhydride. The composition of salt is:—

	Equivalents.	Percentages.
Chlorine	35·5	60·7
Sodium	23·0	39·3

A blue sodium subchloride is (probably erroneously) stated to be produced by passing hydrogen over sodium chloride at high temperatures. Salt is isometric; it crystallizes in anhydrous cubes, and other congeneric forms; its cleavage is perfect; taste, cooling and agreeably saline; when pure, it is white, and is often found in nature in pellucid and perfectly colourless crystals as rock-salt, but more frequently rock-salt is grey, rose, brick-red, yellow, violet, blue, or green, being stained by iron, bitumen, or other impurities. When crystals of salt form by evaporation on the surface of still brine, as frequently occurs in the manufacture, the cubes have a tendency to agglomerate themselves by their angular edges, so as to build hollow four-sided cups, called "hopper-crystals" (Fr., *tremis*). Fishery-, bay-, and dessert- salts illustrate this peculiar form of crystallization. Although salt crystals are anhydrous, they are liable to contain water mechanically intercalated between their crystalline plates, causing them to decrepitate when somewhat suddenly and strongly heated. This decrepitation rarely occurs with rock-salt, and only in a small degree with the heavier larger crystals of salt produced during the slow spontaneous evaporation of sea or other salt water. Salt fuses at 776° (1428° F.), and volatilizes, but not in covered vessels at a temperature approaching its point of fusion, sustaining thereby considerable loss of weight. When a saturated solution is cooled to − 10° (14° F.) or a few degrees lower, it crystallizes in hexagonal tables of hydrated sodium chloride ($NaCl+2H_2O$); and a further reduction of the temperature to about − 22° (− 5·80° F.) causes the separation of bundles of fibrous or needle-shaped crystals, having the composition of a cryohydrate, and containing ten equivalents of water ($NaCl+10\,H_2O$); both these forms deliquesce with the mere heat of the hand, and may be seen to resolve themselves rapidly with a species of decrepitation into sodium chloride solution and numerous small cubes of common salt.

Sodium chloride is decomposed slowly at a red heat in presence of aqueous vapour into caustic soda and hydrochloric acid, according to the formula $2NaCl+H_2O = 2HCl+Na_2O$. This fact has been utilized in an attempt to manufacture soda from common salt, by mixing salt with siliceous sand, placing the mixture in a retort, heating to redness, and passing steam; but the experiment gave no hopes of commercial success.

Salt is nearly as soluble in water at ordinary temperatures as at the boiling-point; and when a saturated solution is heated in a vessel admitting of evaporation, it crystallizes out, forming hopper-crystals at the surface if the liquid be maintained tranquil, or sinking to the bottom as a fine crystalline powder (butter-salt) if the liquor be kept in a state of agitation. Salt is one of the most highly diathermanous bodies, and at the same time one of the most perfect in its absence of thermochroic properties, permitting the passage alike of dark and of visible heat rays, and of heat rays of all degrees of refrangibility. Specimens of colourless pellucid rock-salt are therefore highly prized in researches on radiant heat. Transparent rock-salt transmits no less than 92·3 per cent. of radiant heat from every source, whether the radiating surface be highly incandescent, or the rays be invisible; while the best specimens of flint-glass transmit only 28 per cent. of the heat radiated by red-hot platinum, and still less of dark heat rays; and ice cuts off all radiant heat from either of these sources. Melloni regards clear rock-salt as being completely diathermanous, attributing the 7·7 per cent. by which the intensity of the incident rays is diminished to an effect of reflection at the surfaces of ingress and egress, not to interior absorption.

The annexed table by Poggiale shows the lbs. of pure salt dissolved by 100 lb. of water at various temperatures:—

−15° (5° F.)	dissolve	32·73 lb.	40° (104° F.)	dissolve	36·64 lb.
−10° (14° F.)	,,	33·49 ,,	50° (122° F.)	,,	36·98 ,,
− 5° (23° F.)	,,	34·22 ,,	60° (140° F.)	,,	37·25 ,,
0° (32° F.)	,,	35·52 ,,	70° (158° F.)	,,	37·88 ,,
5° (41° F.)	,,	35·63 ,,	80° (176° F.)	,,	38·22 ,,
9° (48°·2 F.)	,,	35·74 ,,	90° (194° F.)	,,	38·87 ,,
14° (57°·2 F.)	,,	35·87 ,,	100° (212° F.)	,,	39·61 ,,
25° (77° F.)	,,	36·13 ,,	109°·7 (229° F.)	,,	40·35 ,,

According to G. Karsten, a saturated solution of salt at sp. gr. 1·25 contains 26·535 per cent. of NaCl, and saturated at a boiling temperature, it contains 28·225 per cent.

The boiling-points of salt solutions of various strengths are given by Storer thus:—

Aqueous Solution containing per cent. of NaCl.	Boils at ° C. according to		
	Bischof.	G. Karsten.	Legrand.
5	101·50	101·10	100·80
10	103·03	102·38	101·75
15	104·63	103·83	103·00
20	106·26	105·46	104·60
25	107·93	107·27	106·60
29·4	107·9 to 108·99		

According to Gerlach, the sp. grs. of salt solutions at different degrees of concentration are:—

Aqueous Solution, sp. gr. taken at 59° F.	Contains per cent. of NaCl.	Aqueous Solution, sp. gr. taken at 59° F.	Contains per cent. of NaCl.
1·00725	1	1·11146	15
1·01450	2	1·11938	16
1·02174	3	1·12730	17
1·02890	4	1·13523	18
1·03624	5	1·14315	19
1·04366	6	1·15107	20
1·05108	7	1·15931	21
1·05851	8	1·16755	22
1·06593	9	1·17580	23
1·07335	10	1·18404	24
1·08097	11	1·19228	25
1·08859	12	1·20098	26
1·09622	13	1·20433	26·395
1·10384	14		

Salt is found as rock-salt in stratified beds, usually forming large, lenticular or rounded-oblong masses, imbedded in red clays or variegated marls, these being usually interstratified with gypsum or anhydrite. It is likewise one of the chief constituents of sea water, salt lakes, and brine springs, and occurs in small quantities in *all* rivers and springs. It is found in all surface soils, sometimes as an abundant efflorescence. Some desert regions of Asia, N. Africa, N. and S. America, and Australia, appear to owe their sterility to this cause. But probably at no period of the earth's existence did the formation of salt deposits proceed with the same activity as during the Triassic, and it is in the New Red sandstone, Bunter sandstone, or Keuper, and in the red or variegated marls of the Trias, that most rock-salt occurs. An idea that all rock-salt was referable to that epoch long prevailed amongst geologists; but it is now generally admitted that, although salt is found most abundantly amongst Triassic rocks, and becomes rarer as we descend into the earlier strata, it occurs in all the so-called sedimentary rocks. It has not yet been found in granite, nor in any of the crystalline truly so-called primary rocks. In the N. counties of England, are frequent occurrences of brine-springs rising from the Carboniferous series. The Cheshire and Worcestershire deposits are considered by some to belong to the Permian, though most generally they are referred to the Trias. The salts of W. New York, and Goderich (Canada) are said to be of the Salina period of the Upper Silurian. The deposits of the Vosges, Salzburg, and numerous others are generally admitted to belong to the Trias; that of Bex in Switzerland, to the Lias; those of Wieliecska in Poland, and Cardona in Spain, as also some deposits in Algeria, are considered to be Cretaceous; those of the Pyrenees, in the neighbourhood of Bayonne and Dax, and at Camarade, are probably Tertiary; while the Dead Sea, Lake Elton, many other inland lakes, certain estuaries on the shores of the Caspian, the Limans of Bessarabia south of Odessa, the run of Cutch, and the bitter lakes of the Isthmus of Suez, are instances of salt deposits now in actual progress. The last-named lies in a basin which was intermittently inundated by the Red Sea, the waters being evaporated, and beds of salt thrown down, between the successive incursions. At the time the Suez Canal was made, the formation was partially destroyed. Its layers are said to vary in thickness from 1½ to 7½ in., and it is estimated to contain 97 million tons of salt, and to cover an area of 66 million sq. yd. The oldest deposit of rock-salt known to exist, whose geological age may be said to be positively determined, is the Salt Range of the Punjaub, which may with tolerable certainty be referred to the Permian, while the deposits lately discovered at Middlesborough-on-Tees may also probably be referred to this period, as they immediately overlie the magnesian limestone.

Thomas Ward and Von Baer describe the salt formation now going on upon the shores of the Caspian. As at this part it fills with river deposits, a number of bays and gulfs become nearly separated from the main body of the sea; when this occurs on the eastern side, where no rivers enter, and where the evaporation is great, these bays and gulfs soon become intensely salt. Near Novo Petrovsk, on the eastern coast, is a number of basins, presenting every degree of saline concentration. One of these still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom hidden by a thick crust of rose-coloured crystals, like a pavement of marble. A third exhibits a compact mass of salt, in which are pools of water, whose surface is more than a yard below the level of the sea. A fourth has lost all its water by evaporation, and the stratum of salt left behind is now covered by sand. Here we have an instance of what must have frequently happened in the drying up of seas. On the same coast of the Caspian, is the Kara Boghaz, an estuary of considerable extent, and nearly separated from the main body of the sea by a bank, through which there is a shallow inlet. The evaporation from the surface of this gulf is so great that a current continually sets in to it from the main body of the Caspian, and as there is no return current, the water of the gulf is daily becoming more saline, and a salt deposit is being formed, which Von Baer estimates at the rate of 350,000 tons a day. Schleiden says that the Caspian is deprived of nearly 450,000 tons daily by this current, which rather increases the quantity; Von Baer's estimate would give 127,750,000 tons per annum. These figures seem exaggerated, in face of the composition of the Caspian. For every ton of salt conveyed in, there must be 99 tons of water. In process of time, this large gulf will be cut off from the Caspian, and gradually leave enormous beds of salt. On the N.-W. of the Caspian, but some 200 miles from it, are the remains of a similar gulf, Lake Elton, from which large quantities of salt are annually obtained. In 1805, Göbel bored at a distance of about 1⅓ miles from its then shore, and found 42 distinct layers of rock-salt, the uppermost 4 in. thick, the lowermost 9 in. The deeper he went, the purer and more solid was the salt; at the 100th layer (1 ft. thick), it was so hard that the iron tool broke. In time, Lake Elton will disappear like so many others, and its salt will become covered by sand and soil.

The stratified nature of all salt deposits with their interposed beds of clay, the salt rock itself generally possessing a perfectly stratified structure, as well defined as any other rocks of known aqueous origin, points also to the fact that rock-salt must have been deposited from solution. The large quantity of selenite (crystallized hydrated calcium sulphate) so constantly found interstratified and intimately mixed with rock-salt is in itself an almost conclusive proof of its marine origin, for selenite is a hydrated mineral, losing its water at a temperature far inferior to that at which sodium chloride fuses; thus crystals of selenite could hardly have found their way into the solid mass of the salt unless they had been deposited from solution simultaneously with the salt itself. In subsequent times, should the surface of the mixed bed be denuded or dissolved by the action of water, the salt would be carried away, leaving a bed of gypsum, such as is constantly found overlying and surrounding rock-salt deposits. In some districts, as those of Magdeburg, Stassfurt, Vic, &c., beds of potassium and magnesium salts are found overlying the rock-salt. Sea-water contains similar salts, which on its being slowly evaporated are deposited in the same order as and in similar forms to those found in connection with these German salt formations. Supposing the existence of a great Triassic estuary or lake becoming in the lapse of ages completely dried up, it is easy to imagine how the formation of these German deposits took place. Beds of salt would be found, while the inland sea from which they were produced would become continually enriched with successive accessions of salt washed by floods from the salty soil of the surrounding country, and streams would also bring down clay and mud, so that in course of time layers of salt would be formed interspersed with beds of clay, and they might ultimately become covered up and protected by this same clay deposit. In this upper bed of clay, beds of the more soluble potassium and magnesium compounds would remain interstratified.

It has been urged that little or no potassium salts occur in some of the best-known rock-salt deposits; most rock-salt formations, however, show evident traces of denudation subsequent to their formation, as attested by the rounded and waterworn appearance of the exterior surfaces of these beds, indicating that they have undergone superficial re-solution before becoming finally protected by their clay covering. Any denudatory influence of water would first tend to carry off the more soluble potassium and magnesium salts overlying the rock-salt, and only subsequently to this would it attack and dissolve part of the rock-salt, leaving it with a covering of the less soluble gypsum, as already explained. Reniform masses of rock-salt embedded in clay, similar to the larger masses found in nature, may be observed on a small scale in the bottoms of tubs used for dissolving rock-salt. It is perhaps difficult to imagine the enormous lapses of time required in the production of some of the great salt masses. The salt-beds of Cheshire are 75–110 yd. thick in many parts; those of N.-E. France, about Nancy, 7 layers in all, separated by beds of clay, occur at 65 yd. from the surface, and have been proved to be more than 13 yd. deep of salt; those of S.-W. France, at Dax, have been pierced to a depth of 163 yd., without reaching their limit. Whole mountain masses in some countries are largely composed of salt; in Germany, rock has been penetrated to a depth of 1390 yd., of which, all but 94 yd., was in rock-salt. The whole question is one of time, and geologists are daily becoming more accustomed to deal with questions on this basis. It is, indeed, a fact that if the whole of the known deposits of rock-salt in the world were to be added to the waters of the ocean, they would but raise its standard of saltness to an insignificant extent. It has been shown by eminent physical geographers that the surface of the ocean possesses a total area of no less than 132 million sq. miles, allowing 97 million for the Pacific and Indian Oceans collectively, and 35 for the Atlantic Ocean. The quantity of rock-salt which the sodium chloride contained in the waters of the entire ocean could produce, on a basis of an average depth of the ocean of 3 miles (or a bulk of 396 million cub. miles), and assuming 1 gal. of sea water to contain about 0·2547 lb. of salt, and taking 2·24 as an average sp. gr. for rock-salt, 1 cub. mile of sea water would contain such a quantity of salt as would produce 0·01116 cub. mile of rock-salt, which, multiplied by 396 million, gives 4,419,360 cub. miles as the bulk of rock-salt that the evaporation of the entire ocean would yield. This very large figure is equal to 14½ times the cubic contents of the continent of Europe. It is therefore obvious how little the salinity of the sea would have been decreased by the abstraction of such a relatively small quantity of salt as that collectively contained in all the known rock-salt deposits.

It is remarkable how frequently erupted rocks and hot springs are found in the neighbourhood of salt deposits; but this need not be taken as pointing to a volcanic origin for the salt itself. A specimen of salt erupted from Vesuvius in 1822, analyzed by Laugier, gave the following composition:—Sodium chloride, 62·9 per cent.; potassium chloride, 10·5; silica, 11·5; sodium sulphate, 1·2; calcium sulphate, 1·1; ferric oxide, 4·3; alumina, 3·5; lime, 1·3; loss and moisture, 3·7. The very large proportions of potassium and silica distinguish this from any known rock-salt. It is but fair, however, to observe that, on other occasions, considerable quantities of nearly pure sodium chloride have been emitted from this mountain.

It is easy, on the other hand, to understand how depressions and elevations produced in the earth's crust by disturbances due to volcanic phenomena would tend to the formation of estuaries and inland seas favourable to the production of salt; and many such disturbances and eruptions probably occurred during the time when the ocean bed was being raised and became dry land. Further it is to be noted that most trappean rocks are rich in iron, often ferric sulphide, whilst they are easily disintegrated by the combined influences of moisture and atmospheric oxidation. Salt itself assists in promoting such decompositions, so that islands or cliffs of trap on exposure would tend to crumble down and decompose, and under the action of the briny waves of such a sea, some of the iron present might temporarily dissolve as ferrous sulphate, accounting for the frequent red colour of rock-salt. Any sulphur combined with the iron would be oxidized to sulphuric acid, and go to augment the gypsum derived from the sea-water by combining with lime from the surrounding strata, while the crumbled trap, subsiding as clay, and becoming interstratified with gypsum, would wrap up the salt in a protective covering, and preserve it from re-solution.

Another noticeable and not easily accounted for feature in the geology of rock-salt is its frequent association with bitumen and petroleum, which are found with salt in the oil formations of Pennsylvania. Bastennes, where bitumen was long worked, is close to the salt deposits of Dax, at the foot of the Pyrenees; and petroleum floats in small quantity on the surface of a spring near Orthez, and has been found in a boring in the neighbourhood of Salies in the same district. Petroleum and bitumen also occur not far from Volterra in Tuscany, where the largest rock-salt works of Italy exist, and near to which are Count Larderel's celebrated boracic acid springs; and they are worked in some quantities in Wallachia, where also much rock-salt is found. Petroleum has lately been discovered in Hanover, not far from the German salt deposits already mentioned. Bitumen colours the lowest beds of the rock-salt mines of Nancy. It is found in and around the Dead Sea in numerous places, while both bitumen and petroleum occur abundantly at Baku, on the Caspian, near some large salt deposits both old and recent. A good deal of organic matter, both vegetable and animal, exists in the sea, and as its waters became concentrated, such organic matter would concentrate with them. Large quantities of shells filled with petroleum are spoken of as being found in Pennsylvania, and myriads of shells saturated with bitumen occur in the old workings of Bastennes; but whether or no there is any tendency of organic matter in presence of strong brine, through the avidity of brine for water, to develop itself into these hydrocarbons, remains for the present a mystery unsolved. Such a union of facts as here given testifies strongly to the theory that rock-salt is a true sedimentary rock, and that it probably owes its origin to the slow evaporation, in the course of enormous lapses of time, of salt lakes or inland seas fed from the waters of the ocean. The sea as it now exists may owe some of its saltness to the solution of rock-salt formed during previous geological periods, and subsequently depressed beneath the present ocean. Probably such cases of solidification and re-solution have been frequently repeated, but that the present known formations of rock-salt owe their origin to an evaporation of salt water, such as is now going on in certain quarters of the globe, rather than to any eruptive agency, there can be hardly any room to doubt.

The very general distribution of salt in almost every known region of the globe, the facility with which it can be quarried from the mountain sides, or obtained by evaporation from the waters of the sea, or of salt lakes, the fact of its being a prime essential in the economy of life, and a staple raw product of numerous important industries, have led to the introduction of the salt manufacture in one form or other into almost every country, and shed an interest over all facts connected with its production. In considering the various processes by which salt is manufactured, the methods employed in European countries will alone be studied, especially comparing the English manufacture with those in use abroad, where important differences exist. The subject will be divided into 3 heads:—(1) The production of salt from sea-water by spontaneous evaporation; (2) the mining of rock-salt; (3) the production of white salt from brine by evaporation with artificial heating.

Sea-Salt or Bay-Salt (Fr., *Sel marin*; Ger., *Meer-salz*).—The production of salt from sea-water by spontaneous evaporation varies much with the general atmospheric conditions. It was at one time practised in England; at Lymington in Hampshire, at Hayling Island near Portsmouth, and at Saltcoats on the Ayrshire coast, the evaporation of sea-water for the production of salt in "salterns" or "brine-pans" was formerly a staple industry. Since the suppression of the duty on salt, and the development of the production in Cheshire and Worcestershire, the sea-salt industry has been reduced to one or two establishments round the coast where coal is cheap, as at N. Shields, where salt is made by artificial evaporation from strong brine produced by dissolving rock-salt to saturation in sea-water. But the employment of solar heat is common in countries where the climate is more suitable; hundreds of thousands of tons of salt are annually produced in this way along the W. shores of France and Portugal, in the Bay of Cadiz, along the E. of Spain and S.-E. of France, and along the coasts of Italy, Austria, Greece, Turkey, and Russia. The manufacture of salt from sea-water is in fact an industry of high importance, employing much labour, and affording large revenues.

Sea-water differs but little in its composition, whether taken at the surface or at the lowest depths, tides and currents apparently maintaining it in a perfect state of mixture. Some enclosed seas, such as the Red Sea and the Mediterranean, appear to be rather richer in saline matter than the waters of the ocean; others, as the Black Sea and the Baltic, are somewhat poorer. Under the tropics, and where dry winds prevail, there is some trifling augmentation of the saltness of the ocean, whilst at the poles, and near the mouths of some great rivers, the water is rather less salt, but these differences are completely local and relatively insignificant. Table I. (opposite), gathered from various authorities, though it may be considered fanciful in respect of the combinations in which the various elements are supposed to exist, will convey an idea of the composition of sea-waters.

For the better understanding of the processes of manufacturing sea-salt, it will be convenient to consider what are the general results of the concentration of sea-water by evaporation. Usiglio, in some observations very carefully made in the neighbourhood of Cette upon the water of the

Mediterranean during evaporation, describes the reactions and the order in which they take place. The sp. gr. of the water there is 1·023. When the clear water is submitted to concentration by evaporation, no deposit takes place until the water attains a sp. gr. of 1·05, when a little ferric oxide and calcium carbonate begin to go down. This continues till the sp. gr. is 1·12, at which point, selenite (hydrated calcium sulphate) also begins to separate, and continues till the sp. gr. is 1·25. Meanwhile, as soon as 1·21 is reached, i. e. when the original volume of the water is reduced from 1000 parts to 95, magnesium sulphate crystallizes out with the selenite, accompanied by some sodium and magnesium chlorides. Sodium bromide likewise begins to deposit so soon as 1·231 is attained. The precipitation of these 3 salts continues steadily to progress until close upon sp. gr. 1·3, and the volume of the solution is reduced to 16 parts, or about $\frac{1}{63}$ of what it was. Its percentage composition will then be :—Magnesium sulphate, 11·45 per cent.; magnesium chloride, 19·53; sodium chloride, 15·98; sodium bromide, 2·04; potassium chloride, 3·30; water, 47·7. So that when the water had only reached a sp. gr. of 1·21, the only substances which had separated were (in percentages of the original water):—Ferric oxide, 0·0003; calcium carbonate, 0·0117; selenite, 0·1466; but between 1·21 and 1·231, the composition of the deposit became:—Calcium sulphate, 0·0283; magnesium sulphate, 0·0621; sodium bromide, 0·0222; magnesium chloride, 0·0153; sodium chloride, 2·7107. Thus between these two last-named densities, nearly 2·84 per cent. of saline matter crystallized out of the solution, 95½ per cent. of this being sodium chloride.

These results are most instructive, and their application in the art of salt production from sea-water will presently be seen. Usiglio further describes the reactions which follow on continuing the evaporation of the mother-liquor; how they become more complicated, and the composition of the material which salts out commences to vary with alternations of temperature; how, if the temperature of this mother-liquor of sp. gr. 1·3 be lowered, as by exposure during the night, magnesium sulphate alone will crystallize, whereas if the liquor be concentrated by further evaporation during the day, a mixture of sodium and potassium chlorides with magnesium sulphate goes down. By this deposition, the solution slightly loses in density, and its sp. gr. may possibly fall to about 1·28. Magnesium bromide also separates with the potassium and magnesium chlorides, and a double potassium and magnesium sulphate forms, corresponding with the kainite of Stassfurt ($K_2SO_4MgSO_46OH_2$). There likewise separates another double salt, corresponding to the Stassfurt carnallite (potassium and magnesium chloride, $KClMgCl_26OH_2$). Finally, the mothers, which now have attained a sp. gr. of 1·333, retain scarcely any sodium chloride or magnesium sulphate, very little potassium chloride, and are in point of fact a saturated solution of nearly pure magnesium chloride. This last salt crystallizes if the temperature be lowered to about 4½° (40° F.).

TABLE I. COMPOSITION OF SEA-WATERS.

LOCALITIES.	English Channel.			Atlantic.		Mediterranean.		North Sea.	Caspian Sea.	Black Sea.	Dead Sea.
AUTHORITIES.	Riegel.	Schweitzer.	Laboulaye.	Ure.	Boullion, Lagrange et Vogel.	Laurent.	Ann. de Ch. and Ph., Sept. 1849.	Clemm.	H. Rose.	Gobel.	Fleck.
CONSTITUENTS.											
Sodium chloride	2·4632	2·7060	2·50	2·789	2·510	2·722	2·9421	2·484	0·754	1·4019	7·405
Potassium chloride ..	0·0307	0·0765	..	0·154	..	0·001	0·0505	0·135	..	0·0189	1·690
Magnesium chloride ..	0·2564	0·3666	0·35	0·233	0·350	0·614	0·3219	0·242	..	0·1305	12·811
Calcium chloride	0·0439	..	..	..	..	..	..	..	..	..	3·536
Magnesium bromide ..	0·0147	0·0030	..	..	..	..	..	..	..	0·0005	..
Sodium bromide	..	..	..	0·052	..	..	0·0556	..	..	..	0·502
Calcium sulphate	0·1097	0·1406	0·01	0·155	0·015	0·045	0·1357	0·120	..	0·0105	0·121
Magnesium sulphate ..	0·2146	0·2300	0·58	0·184	0·578	0·702	0·2477	0·206	0·406	0·1470	..
Sodium sulphate	..	..	..	..	..	..	..	..	0·036	..	1·217
Calcium carbonate	0·0176	0·0030	0·02	..	} 0·020	0·020	{ 0.0114	..	0·018	0·0365	..
Magnesium carbonate ..	0·0078	..	..	..			..	..	0·440	0·0289	..
Ferric chloride	..	..	..	..	..	..	0·0003	..	..	..	..
Water	96·8414	96·4743	96·54	96·433	96·527	95·896	96·2904	96·813	98·346	98·2253	73·926
Total..	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·
Percentage of solid constituents	3·1586	3·5257	3·46	3·567	3·473	4·104	3·7655	3·187	1·654	1·7747	26·065

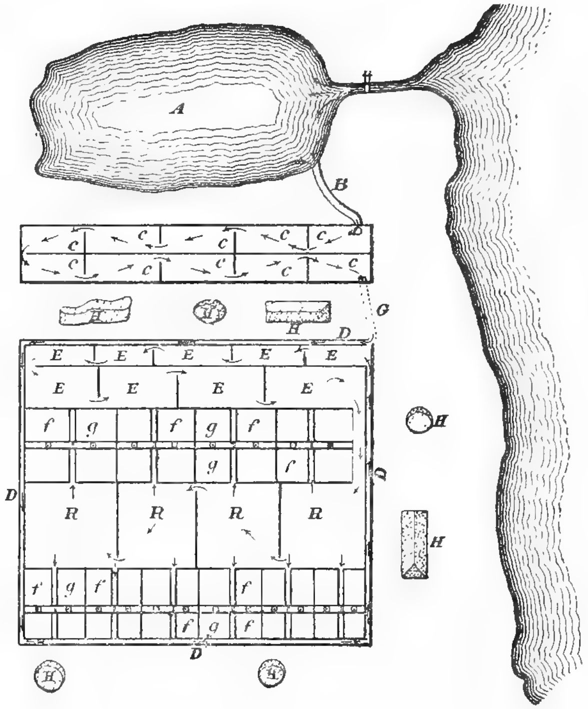
The works in which the sea-salt industry is carried on consist of several series of basins communicating with one another, and possessing extensive evaporating surfaces. Through these, the sea-water is led until arriving in the last, which are very shallow; the already concentrated salt water is allowed to stand till most of the salt has crystallized out.

The mother-liquor or "bittern" is drawn off, and the salt is collected and drained to dryness. The first of the series of basins is usually a large shallow pond, into which the sea-water is admitted, and where it is allowed to settle, and is stored for use. Sometimes two such large basins are employed, one for settling, the other for storage. Hence the water is carried through a series of other basins, each set in its turn being smaller and shallower. In the last, the salt principally deposits; it is then collected, drained, and stacked for sale.

These works are called by various names, according to the countries in which they are situate. In England, they were known as "salt-marshes," "salterns," "salt-gardens," and by other local names. In France, they are called *marais salants* or *salins*; in Portugal, *marinhas*; in Germany, *Meersalinen* or *Salzgärten*.

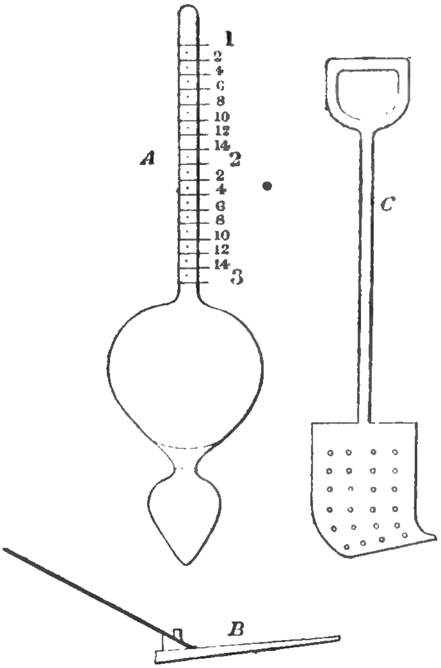
Fig. 1203 shows a *marais salant* as now in use on the Atlantic coast of France. The spot chosen is generally some little bay or creek protected from the direct action of the waves; from this, is led a small canal, through which at spring-tides the sea-water can be conducted into the large reservoir A, the *jas* or *vasière* ("settler"), where the water is allowed to clarify. This reservoir is usually placed higher than the rest of the *marais salant*, so that the water can be run off at pleasure into the first set of basins or *couches* c, without pumping. The *jas* may be of any moderate dimensions, and often covers 2¼ acres, the depth varying from a yard to a fathom. The water, having become thoroughly clarified in the *jas*, is allowed to run by the underground channel B, fitted with a suitable sluice, to the *couches*, which are frequently about 23–24 ft. long, 12 ft. wide, and 1–1½ ft. deep, arranged in sets of 8 or 10 in a double row, as shown, separated by low walls or dams, but communicating with each other in such a manner that the water entering from A by the sluice B can circulate slowly through them, as shown by the lines and arrows, and be drawn off by the sluice G. In fine weather, the water has already undergone some degree of concentration by the time it has settled in the *jas* A, and as it passes in an almost insensible current through the *couches*, it continues to evaporate. It is led by the sluice G into a canal D, which nearly encircles the *marais salant*, and serves to conduct the water on to the *tables* E, arranged similarly to the *couches*; over these, it flows as before in an almost insensible current into other basins R, called *adernes* or *muants*, whence it is fed as required by small channels cut in the soil into the *œuillets f g*, small basins where the salt crystallizes, or, as the French peasants say, "*où l'eau commence à saliner.*"

1203.



On the shores of the Mediterranean, about Cette, Marseilles, and the Étang de Berre, immense quantities of salt are produced by a somewhat similar arrangement. As, however, there are no tides in that sea, the arrangement with the separate reservoir A is not essential. A series of basins, whose bottoms are levelled and pugged with clay, are made by sets in gradients (usually 3), so arranged with channels and sluices that the water can flow from basin to basin and from one set to another. The general principles involved are much the same as on the Atlantic coast. They differ, however, in the degree of circulation of the water. In the western works, the water is allowed to almost stagnate, as it were, no differences of level being maintained so as to promote its flow, except in respect of the *jas*, which is usually placed on a rather higher level. In the *salins du midi*, on the contrary, when the flowing water has reached its lowest gradient, it is collected in large wells, whence it is drawn up and thrown back by a pump or water-wheel to its former level, and again traverses a like set of gradients, to return once more to another set of wells. The first set are called "wells of green water," the second are called "salt water" wells. On arriving at these latter, the water should have attained a sp. gr. of 1·18–1·20, and be nearly at crystallizing-point. By this means, a greater circulation is maintained, and the evaporation is more rapid. Each set of basins in each gradient is made a little smaller than the previous set, to correspond with the diminishing bulk of the water as it undergoes evaporation. Finally, in a set of basins placed at the lowest level of all, the salt crystallizes; these are called *tables salantes* or *crystallisoirs,* and receive the water so soon as it has attained a sp. gr. of 1·95–2·00. In the salt marshes of the west, the mother-liquor ("bittern") is always left in the *œuillets,* and has a tendency to render the salt rather bitter and deliquescent, by reason of contamination with magnesian salts. In the *salins du midi,* as the French Mediterranean works are called, the bittern is drawn off, and stored in special reservoirs, with a view to its subsequent further evaporation, alternated with refrigeration, for the extraction of the potassium and magnesium salts. When the salt has formed in the *œuillets* or on the *tables salantes,* as the case may be, more ready-concentrated water is run on, the bittern being drawn off in the case of the *salins du midi,* or left in the *marais salants* of the west. Here the water is maintained at a depth of 3–4 in., and a fresh supply is run in every 2 days or so during fine weather, and when enough salt (say 3–4 in.) has accumulated, it is collected by means of a sort of scoop or hand plough B, Fig. 1204, which the *saulnier,* as these workmen are called, pushes along before him. Notwithstanding that he does this work with surprising dexterity, he never fails to pick up a considerable portion of clay with the salt, rendering the latter impure. Of late years, a species of moss has been introduced from the Portuguese marshes into the *salins du midi.* This is grown under fresh water, with which the basins are flooded for the purpose, and forms a clean bed, whereon the salt crystallizes, and is thus obtained far whiter and purer. The salt of the French Atlantic coast often contains not over 88 per cent. of sodium chloride; the Marseilles and Cette salt, over 95 per cent. The salt, after collection, is stacked in heaps H around the *marais salant,* these often being thatched over for protection from rain, and it there drains and loses much of its deliquescence and bitterness by long exposure to the atmosphere. In France, this work lasts in fine summers from April till September.

1204.



The sea-salt trade is far more prosperous on the Mediterranean than on the Atlantic sea-board, for not only is the salt far purer, but less rain falls in the former locality, and that part of the Mediterranean coast bordering on the Gulf of Lyons is very subject to a dry parching wind called the mistral, which, though a great disadvantage to the other inhabitants of the country, blows much profit to the salt-makers. Nobody can imagine more miserable creatures than the poor *saulniers* of the W. coast of France; clothed in rags and more than half starved, pale and shivering with ague, they still struggle to maintain an industry which is gradually dying out. The pan-salt of the S.-W. works of Dax, Salies, Briscous, and Villefranche is competing with them on the one hand; while the more successful *salins du midi* are now able with improved means of communication to bring their salt, which is both better and cheaper, into the markets of their western competitors at Bordeaux, Agen, Perigeux, and Pau; and the salt of the N.-E. of France has driven them from Paris. Looking at the condition of the people, it is little to be desired that this industry should last in the W. of France, and it is much to be wished that they should turn to other employment.

The sea-salt industry of the coast of Portugal is very extensive, that relatively small country producing annually 250,000 tons, of which the salt-works of Sertuval alone yield 150,000 tons. In the districts of St. Ubes, Alcacer do Sal, there are over 400 sets of sea-salt works; and at Aveiro, Figueras, and Oporto, are others of very great importance. In Istria, the sea-salt works of Pirano and Capo d'Istria yield annually 60,000 tons, while the "gardens" cover an area of 9 million sq. yd. In Sardinia, 50,000–60,000 tons of sea-salt are annually produced near Cagliari; while for the rest of Italy, Trappani, Lungro, Cervia, Margherita de Savoia, Comachio, etc., yield 105,000–

120,000 tons. Spain, in the salt marshes of the Bay of Cadiz, Marbella Roquitas, Guandamar, and in the Balearic Islands, produces some 300,000 tons. In Russia, very large quantities of sea-salt are made in the Limans of Odessa, on the shores of the Crimea, and on the N.-E. coast of the Caspian.

The production of sea-salt in France is shown in the table on p. 1737.

The manufacture of sea-salt would appear to be a profitable concern in the Eastern Archipelago. The following is an estimate of the cost of carrying on the manufacture at the salines of Baria. The space allowed for the tables is about 40 per cent., the beds 40, and the *jas* 20. To establish 200 acres of "tables," requires no less than 250 acres of land. The working of 1 acre of tables, or 2½ acres of saline, involves the following expenditure:—1500 *fr.* for feeding the workmen during the formation of the salines; if the first collection of salt is good, the workpeople are paid a second sum of 1500 *fr.*, and the collection of salt is given over to them for their own benefit. The capital thus advanced amounts to 3000 *fr.* The second year the proprietors work on their own account, and may collect salt to the value of 2000 *fr.* After deducting tax, etc., there remains about 1200 *fr.* of net revenue on the capital advanced at different stages (3000 *fr.*), or about 36 per cent.

In India, where the Government monopolizes the sale and manufacture of salt, the annual consumption during the years 1867–8 amounted to 22,700,000 *maunds* (of 82¼ lb.), in 1878–9, 24,200,000 *maunds.* The duty varies from 1*s.* to 6*s.* 6*d.* a *maund.* The bulk of this salt is obtained from the evaporation of sea-water or from the Sambhur Lake, but the output of Punjab rock-salt was in 1878–9 estimated at over 600,000 *maunds.* The quantities of white salt sent to India from this country will be seen on p. 1736.

Extensive salt fields exist at Shimpaga, a short distance above Mandalay, on the W. bank of the Irrawady. It is also obtained at other places in Burma on a small scale. Large quantities could be manufactured at Shimpaga, but imported salt is fast taking its place in the market.

Table II. shows the compositions of some of the sea-salts known in the markets of Europe:—

TABLE II. ANALYSES OF SEA-SALTS FROM WELL-KNOWN LOCALITIES.

LOCALITY.	St. Ubes.						St. Martin.	From Brittany, Marais Salants de l'Ouest.	Island of Oleron.	Salins du Midi.	Cadiz.	St. Felice Trappani.	
AUTHORITY.	Henry.	Berthier.		Karsten,			Henry.	Enquête sur les Sels.	Henry.	Enquête sur les Sels.	Watts.	Schrotter and Pohl.	
CONSTITUENTS.													
Sodium chloride	96·00	95·19	89·19	95·86	92·46	96·50	95·95	87·97	96·40	95·11	92·11	95·91	96·50
Magnesium chloride ..	0·30	..	..	0·24	0·55	0·32	0·35	1·58	0·20	0·23	..	0·46	0·50
Magnesium sulphate ,,	0·45	1·69	6·20	0·35	0·66	0·25	0·60	0·50	0·45	1·30	0·99	0·40	0·51
Sodium sulphate	..	..	..	..	..	..	..	..	..	..	..	..	..
Calcium sulphate	2·35	0·56	0·81	1·30	2·28	0·88	1·90	1·65	1·95	0·91	0·33	0·49	0·45
Water	..	..	0·20	2·10	3·10	1·95	..	7·50	..	2·35	6·30	2·58	2·42
Insoluble matters.. ..	0·90	2·45	3·60	0·15	0·95	0·10	1·20	0·80	1·00	0·10	0·27	0·16	0·07
Loss,.	..	0·11	..	..	..	..	..	..	..	..	..	..	..
Total .. .,	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

There is one other method of salt manufacture employed in countries where extreme cold prevails, and which deserves passing mention. When sea-water is frozen, fresh water alone congeals, and the residue is a highly concentrated solution of its saline contents. This solution, further concentrated by evaporation, yields crystals of common salt. In the Russian province of Okhotsk, this industry is carried on to some extent during the winter months, but to judge from the annexed analyses by Hess, the salt so obtained is not of superior quality:—

	1st crystallization.	2nd crystallization.	3rd crystallization.
Sodium chloride	86·0	79·1	77·6
Aluminium ,, ...	3·6	7·8	6·2
Calcium ,, ...	0·9	0·7	0·9
Magnesium ,, ...	2·0	0·8	1·7
Sodium sulphate	7·5	11·6	13·6
	100·0	100·0	100·0

Salt is also made in small quantities in Holland and some other countries of N. Europe by dissolving rock-salt to saturation in sea-water, and evaporating the solution by artificial heat, as will hereinafter be described under white salt. The salt so obtained is merely for local consumption, and the business is not important enough to merit more than passing allusion.

Rock-Salt (FR., *Sel Gemme*; GER., *Stein-Salz*).—The geology of rock-salt has been already pretty fully considered in the commencement of this article. In a paper read before the Literary and Philosophical Society of Liverpool, Thos. Ward gives a classification of the principal rock-salt deposits of Europe, which is deserving of reproduction almost *in extenso.*

The great salt districts of Europe in which rock-salt or brine-springs are met with are:—(1) Carpathians, (2) Austrian and Bavarian Alps, (3) W. Germany, (4) Vosges, (5) Jura, (6) Swiss Alps, (7) Pyrenees, (8) Spanish or Celtiberian Mountains, (9) isolated deposits and springs in Russia, Turkey, Italy, Prussia, British Islands, &c., and (10) Cheshire, Worcestershire, &c.

1. The Carpathians.—This is the most extensive and rich salt district in Europe, possessing salt enough to supply the whole continent for several thousand years. The Romans mined salt in various parts of Transylvania, and down to the present time salt is obtained from that country. From the extreme west of Galicia, following the direction of the Carpathians to where they meet the Danube, salt is more or less widely distributed on both slopes of the chain. The district may be divided into the Moldo-Wallachian, Transylvanian, Galician, and Hungarian sections.

The salt-mines of Wallachia are very noted, and the salt is distributed by means of the Danube and its tributaries over Bulgaria, Servia, and Hungary, as well as over the home districts. The salt used is the rock-salt, as is generally the case throughout the district of the Carpathians. Owing to the absence of cheap fuel, and the tolerable purity of the rock-salt, very few attempts to manufacture white salt have been made, and millions of gallons of nearly saturated brine are allowed to run to waste. The mines at Stanikul̆, Kimpina, Okna, and Okna Mare are the most important in Moldo-Wallachia.

Transylvania is richer in rock-salt than any other portion of Europe. It consists of a central basin, that of the Máros river, and the basins of the upper courses of the Számos and Alt rivers. The whole territory is more or less mountainous, and the deposits of rock-salt are frequently found along the banks of the small rivers amongst the hills. The supply of salt is inexhaustible. The great centres of salt-mining are Máros Ujvar, on the Máros river, most favourably situated for water communication, and hence the largest shipping town in the district, exporting seventy per cent. of the Transylvanian salt; Parajd, on the Korond, a tributary of the Máros; Dées Akna, on the Great Számos; Számos Ujvar, on the Little Számos; and Vizakna, on a small tributary of the Máros. The mine at the small town of Sasmezö, in the Ojtoszer Pass, forms a connecting link between the Transylvanian and Moldo-Wallachian districts. The generality of the mines lie near the surface, though the salt is followed downwards to great depths. The quantity of salt mined is very small compared with that in English mines. The whole annual production of Transylvania is estimated at 50,000 tons, about ⅛ of the production of all kinds of the Austro-Hungarian empire.

The Galician district extends along the N. and N.-E. slopes of the Carpathians, from Moldavia to Moravia. There are numerous mines and brine-springs scattered at intervals along this district. The most celebrated salt-mines in the world, and those longest worked, are the mines of Wieliczka and Bochnia, at the extreme west of Galicia. The mines at Wieliczka have been worked since the 13th century. The mines and works of Sanok, Starasol, Kaluscz, and numerous other places, send out considerable quantities of salt; and recently there has been discovered in the Kaluscz mine, sylvin, or native potassic chloride, and magnesic sulphate.

The Hungarian salt district is very extensive, but almost wholly confined to the region of the Carpathians, from the borders of Transylvania to Moravia. One of the largest tracts lies in the basin of the Számos, in the neighbourhoods of Szathmar and Szigeth, and in the neighbouring districts of Marmaros. In the localities of Soovar and Szlec, in the extreme north of Hungary, there are numerous mines. A continuous series of salt deposits is thus traceable from the neighbourhood of the Alt in Wallachia, along the Carpathians (and the minor chains running from them) around Transylvania, and thence on both slopes of the same mountains between Galicia and Hungary, until the Sudetic mountains are reached.

2. The Austrian and Bavarian Alps.—This is probably the best known salt district of Europe to ordinary travellers. The most important mines and springs lie in a comparatively small area, in the upper parts of the basins of the Traun and Salza, and partially in the basin of the Inn. The most celebrated region is the Salzkammergut, lying on both sides of the river Traun, on the borders of Styria and Salzburg. The salt is chiefly manufactured. In many cases, water is allowed to run into the rock-salt mines, and to become saturated brine, then drained off, and manufactured, many miles away. The district extends into Bavaria, along the valley of the Salza. The most important salt towns in the Austrian portion are Aussee, Ischl, Hallstätt, and Hallein. The Bavarian portion is very rich in salt, the chief towns being Berchtesgaden, Reichenhall, Traunstein, and Rosenheim. The last-named manufactures the salt from brine conveyed in pipes from

Reichenhall. This alpine district extends into the Tyrol; at Hall, near Innsbruck, in the Inn valley, are very extensive salt deposits and salt-works, and the rocks are similar in character to those of the Salza and Traun.

3. W. Germany.—Under this head, are classed a very large number of salt-mines and brine-springs extending from Segeberg, in Holstein, in the north, to Sulz, on the Neckar, in Württemberg, on the south, and from Kreuznach on the Nahe, on the west, to Halle near Madgeberg, on the east. As they are by no means equally spread over the district, it will be well to group them as much as possible. The first group lies in the valley of the Neckar, and one of its chief tributaries, the Kocher. The Black Forest mountains form the west boundary, and the Suabian Jura the east. The chief towns are Sulz, Wilhelmsglück, Hall, Wimpfen, Neckar-Sulm, and Sulzbach. In the valley of the Main and its tributaries, are a few brine-springs. At Hallstadt and Nidda, a large quantity of salt is made; and at Kissingen, is a very strong brine-spring.

The district between the Elbe and Weser contains very large quantities of salt, and springs of brine are met with in great numbers, from the banks of the Werra and Saale, to those of the Aller. The most numerous springs, as also the rock-salt deposits, lie near the various small ranges of mountains that are scattered about the district, as the Thuringer Wald, Harz Mountains, Tentoberger Wald, &c. The most important towns are Salzungen, Allendorf, Halle, Stassfurt, Salza, Schönebeck, Harzburg, Neustadt, Salzgitter, Salzderhelden, Salzwedel, Hildesheim, Rodenberg, Sulze, Luneberg, &c. Closely connected with this district is the Ruhr Valley in Westphalia, in the neighbourhood of Unna, where are numerous brine-springs. Two localities of special importance are the district between Magdeburg and Halle, more especially in the neighbourhood of Stassfurt; and the Luneberg Heath in Hanover, to the south of Hamburg. In both localities, brine-springs have long been known, and Schönebeck and Luneberg have been centres of salt manufacture for a considerable period. It is only of late that the extensive deposits of rock-salt in both neighbourhoods have been discovered. There is one more small district lying quite outside the others, that of Oldesloe and Segeberg, in S. Holstein. At Oldesloe, a brine-spring has been worked for a very long period. It is but within the last few years that rock-salt has been found at Segeberg.

4. The Vosges.—This is a very important district. Its salt meets English salt very extensively in Belgium. Great portions of E., N., and Central France are supplied from it. Until the late Franco-German war, the district belonged wholly to France, but, lying in the ceded district of Alsace-Lorraine (principally in Lorraine), now belongs to Germany, thus rendering Germany the possessor of some of the most extensive salt deposits in Europe. The chief towns in the Vosges district lie in the neighbourhood of Metz and Nancy, and are Chateau Salins, Dieuze, Moyen Vic, Sarrealbe, Salzbron, Rosière. The salt is chiefly manufactured from brine-springs, though a considerable quantity of rock-salt is mined at Vic, and at Varengeville, near Nancy.

5. The Jura.—Since France has lost the salt district of the Vosges, the long-noted one of the Jura will become of more importance. It is separated from that just mentioned by the Plateau of Langres, and lies in the basin of the Saône and Doubs. The salt-springs of Salins have been noted from remote antiquity. The chief centres of manufacture are Salins, Arc, Lous le Saulnier, Montmorot, Saulnot.

6. The Swiss Alps.—This small district lies on the right bank of the Rhone, just before the river enters the Lake of Geneva, in the Canton de Vaud. It has rock-salt mines and brine-springs. The chief centres are Aigle, Bex, and Roche. Rock-salt was mined here 300 years ago.

7. The Pyrenees.—Like the Carpathians, the Pyrenees are rich in rock-salt deposits and brine-springs. In the W. district of the Pyrenees, in both France and Spain, salt appears to be most plentiful. In France, the basin of the Adour is the most important district, and contains the towns of Salies de Béarn, Briscous, Villefranche, which last forms almost a suburb of Bayonne. Dax was discovered accidentally by Ward a few years ago. At Salies d'Arbas, on the Garonne, near the Pyrenees, a brine-spring exists, and salt is manufactured. In Spain, the whole basin of the Ebro is rich in salt, especially towards the source of the river, as is indicated by the number of villages named either *sal* or *salinas*. In one small district, are Salinas, Salinas d'Amana, Salinillas, Poza de la Sal. On the banks of the Ebro, are Mendavia, Valtierra, Remolinos, and Sastag. Both rock-salt and brine-springs are plentiful. One of the most peculiar deposits of rock-salt known to exist is in this district, about 45 miles N.-W. of Barcelona, on the banks of the Cardona river; this is the famous rock-salt mountain of Cardona, a hill composed entirely of rock-salt, which is worked in open quarries like stone.

8. The Celtiberian or Spanish District.—This is rather a number of isolated mines and brine-springs. The chief towns are Saelicas, in the province of Guadalajara; Torreximeno, in the province of Jean; Villafafila, in the province of Zamora; Monteagudo and Minglanilla, in the province of Cuenca; Cazorla and Hinojares, in Andalusia; and Jumilla, in the province of Chinchilla. There are indications of salt in various other places; indeed, Spain seems richly endowed with this mineral.

9. Isolated Salt-Deposits and Brine-Springs.—In France, at the foot of the Alps, at Moutiers and Castellane, are well-known brine-springs from which salt is made. These may possibly belong to the same district as those of Aigle and Bex. In Italy, at Volterra in Tuscany, salt is manufactured; and at Lungro and Altamonte, in the mountains of Calabria, rock-salt is mined. In Sicily, at Nicosia and Mussomeli, are salt deposits. At Szamobor, in Croatia, and Tuzla, in Bosnia, salt is found. In Russia, at Bachmutz, on the Donetz; Balachna, on the Volga; Staraia Russa, near Lake Ilmen; Solikamsk, on the Kama, and the neighbourhood of the Ural Mountains; and at Iletzkaya, salt deposits exist; also at Eupatoria, in the Crimea, rock-salt is found. In Prussia, at Jnowraclaw, Rawicz, Waltersdorf, brine-springs are found; and at Sperenberg, S. of Berlin, a bed of rock-salt, of the enormous thickness of 2810 ft., had been bored into in 1870. At Kreuznach, on the Nahe, rock-salt is mined: this seems to be connected with the Vosges.

10. Cheshire, Worcestershire, &c.—The chief centres of rock-salt and brine-springs are Northwich, Middlewich, Winsford, Sandbach, in Cheshire; Weston-on-Trent, in Staffordshire; Stoke Prior, and Droitwich, in Worcestershire. At Duncrue, near Carrickfergus, there is an important rock-salt deposit. At Middlesborough-on-Tees, another valuable deposit of rock-salt exists. At Chester-le-Street, in Durham, is a brine-spring. Indications of salt are to be met with in Staffordshire, Shropshire, and Lincolnshire. The Cheshire and Worcestershire deposits are by far the most important among British rock-salt deposits, the Carrickfergus salt being only worked to a comparatively limited extent, and the Middlesborough hitherto not at all. This last was discovered some years ago by Bolckow, Vaughan, & Co., while boring for water in their steel-works, but they were unable to follow up the discovery for want of sufficient room. Bell Bros. have now bored in the meadows in front of their works at Port Clarence, where, at a depth of a little over 300 yd., they have again found the salt, and have traversed the bed to a thickness of about 33 yd. No doubt with cheap coal and the facilities for shipment existing at the spot, as well as its proximity to the important industrial centres of the Tyne, the Wear, and the Tees, and its central position on the E. coast of England, the produce of this deposit may some day find its way to the Baltic, and supply part of the Scotch and English fisheries, and figure as an important factor in the salt industry of England.

Rock-salt, as such, is comparatively little worked in England at the present day, only about 115,000 tons being annually sent down the river Weaver, and most of this coming from the celebrated Marston mine, owned by Fletcher and Rigby of Northwich. This is the most extensive rock-salt mine in Great Britain. The rock-salt is mostly exported to Belgium, and some other Continental countries. Germany used to take some rock-salt from England, but since her own discoveries, this trade has greatly diminished. Some consumption of ground rock-salt has sprung up of late, for use in the Hargreaves process of making "salt-cake" (see p. 287), for which it is better suited than the ordinary chemical salt. The rock-salt was first discovered at Marbury in 1670, in trying for coal, and for about a century subsequently only the upper layer of salt was known and worked. As far as the deposits in the neighbourhood of Northwich are known, each is said to consist of two superimposed beds, and to form two separate blocks, about 1½ miles long and 1300 yd. wide, but they are obviously far larger than this. The salt is reached at depths varying from 32 to 53 yd. (at Marston, 37 yd.), by sinking through beds of variegated clays or marls interstratified with layers and nodules of gypsum. The upper bed of rock-salt possesses a thickness of 25–30 yd., but rapidly thins off towards the S.-W. Above this bed of salt, and lying apparently in the recesses of its surface, is found a more or less continuous layer of saturated brine. This is the brine which, extracted at the various pumping-stations of Northwich, Winsford, and other places, and evaporated as described later on, supplies the white salt of the works of these districts. It has obviously been produced by leakages or infiltrations of the surface water through fissures in the superincumbent strata, and this by prolonged contact with the rock-salt has become converted into brine. Once saturated with salt, this brine lies inert upon the rock-salt, producing no further solvent action, until, some of it being withdrawn by pumping, more fresh water flows in from above, or until water, entering the strata at any outcrop which may exist on higher grounds, forces the brine out to the surface as natural springs, and continues the solution of the rock-salt. It is estimated that the quantity of brine pumped in the Cheshire salt districts must in this way annually withdraw not less than 1,122,900 cub. yd. of rock-salt from the subjacent strata, leaving the ground above practically unsupported. In many places, serious damage to property has arisen from this cause, and, in a bill lately attempted to be introduced before Parliament, it was proposed to compensate the losses and destruction of property consequent upon these subsidences by a tax of 3*d.* a ton to be levied on all the salt manufactured in the Cheshire districts; but the bill was rejected. A very exhaustive inquiry was made by a select Committee of the House of Commons on this occasion, which lasted from May 5th to May 20th of the present year, into the geological relations of the Cheshire saliferous strata. Several interesting points were raised as to the causes of the subsidences, and De Rance, of the Geological Survey, among others, afforded some valuable historical and practical scientific evidence, the general conclusions at which he arrived being:—1. That the brine is formed by the natural descent of water through the porous strata of the high grounds surrounding the geological basin of Cheshire on to the saline beds. 2. That the brine so formed passes by gravitation through the strata, emerging from it in several places at the surface of the ground. 3. That this wastage of the saliferous beds has, previously to the interference of man, caused large subsidences in historic times, and is likely still to continue to do so. The evidence adduced with regard to the existence of natural brine-springs and the records of previous subsidences were very interesting, and it seems difficult to imagine how now, after some centuries of working, and in view of the above facts, a tax such as that proposed could be levied on the saltmakers without injustice. One very curious map was placed in the hands of the committee, showing how very large have been the workings in the Northwich region, and that, practically speaking, nearly the whole district is undermined by the excavations for rock-salt, most of these being in the upper bed, and this was held sufficient to account for much of the subsidence in that region. In France, similar accidents have occurred, only to a less extent, from similar causes; and part of the fortifications of the town of Dieuze having been injured by subsidence in the celebrated salt-mines of that place, the waters of the Indre having penetrated into the mines and dissolved the supporting columns of salt, the French Government felt bound to legislate on the matter. The mine of Varengeville, St. Nicolas, also fell in a few years since, causing some loss of life, and considerable destruction of property. Beneath the upper bed of the rock-salt at Northwich, lies one of a kind of greystone, interstratified with veins of salt. This bed of saliferous stone is 10½ yd. thick, and overlies the second or great bed of salt, below which it reappears, and has been sunk into to a further depth of about 62 yd. in another mine adjoining the Marston, where some small layers of salt were found, but of inferior quality. The second bed is the one from which the principal supplies of British rock-salt are now drawn; and at Marston, it has been explored to about 33 yd. in thickness. The Marston mine has been worked for over 100 years, is 120 yd. in depth, and covers an area of about 40 acres. Round the base of the shaft, the roof of the mine is supported by eight huge pillars of rock-salt, each pillar being 30 yd. long by 10 yd. wide. The rest of the mine is equally supported by pillars, between which the salt has been worked out; these are 10 yd. sq., and 25 yd. apart. The main or principal cutting in the mine is called by the miners Piccadilly. The salt is blasted out with gunpowder in the ordinary fashion, and sent up in bens to the surface; the best and purest portions are selected for sale, while those which are too much contaminated with clay are rejected. This description of a rock-salt mine might be repeated for nearly every other salt mine in the world, with the sole difference that in some (as in Wieliczka) the workings are on a more vast and important scale.

The accompanying nomenclature of the strata traversed by the sinking for rock-salt at Witton, near Northwich, shows the position of the Cheshire salt, as given by Holland:—

		Yd.	Ft.	In.
1.	Calcareous Marl	5	0	0
2.	Indurated Red Clay	1	1	6
3.	Indurated Blue Clay, with Sand	2	1	0
4.	Argillaceous Marl	1	2	0
5.	Indurated Blue Clay	0	1	0
6.	Red Clay, with Sulphate of Lime irregularly intersecting it	1	1	0
7.	Indurated Blue and Brown Clay, with grains of Sulphate of Lime interspersed	1	1	0
8.	Indurated Brown Clay, with Sulphate of Lime crystallized in irregular masses and in large quantity	4	0	0
9.	Indurated Clay, Blue, laminated with Sulphate of Lime	1	1	6
10.	Argillaceous Marl	1	1	0
11.	Indurated Red Clay, laminated with Sulphate of Lime	1	0	0
12.	Indurated Blue Clay, laminated with Sulphate of Lime	1	0	0
13.	Indurated Red and Blue Clay	4	0	0
14.	Indurated Brown Clay, with Sand and Sulphate of Lime interspersed through it. The fresh water, 360 gal. a minute, finds its way through holes in this stratum, and has its level 16 yd. from surface	4	1	0
15.	Argillaceous Marl	1	2	0
16.	Indurated Blue Clay, with Sand and grains of Sulphate of Lime	1	0	9
17.	Indurated Brown Clay, with little Sulphate of Lime	5	0	0
18.	Indurated Blue Clay, with grains of Sulphate of Lime	0	1	6
19.	Indurated Brown Clay, with Sulphate of Lime	2	1	0
20.	First bed of Rock-Salt	25	0	0
21.	Indurated Clay or Stone, with veins of Rock-Salt running in it	10	1	6
22.	Second Bed of Rock-Salt	36	0	0

The following analysis of the beds of "stone" underlying and intercalated between the beds of salt may be of interest, as a matter of comparison with the composition of pan-scale, and of the deposits formed during the evaporation of sea-water:—

	Per cent.		Per cent
Water (at 212° F.)	1·86	Sulphuric acid (SO_3)	2·16
Loss on ignition (including traces of CO_2)	6·62	Phosphoric acid (P_2O_5)	1·95
		Insoluble residue:	
Lime (CaO)	3·37	Alumina	9·45
Ferric oxide (Fe_2O_3)	5·80	Silica	44·51
Alumina (Al_2O_3)	7·85		
Sodium chloride	15·60	Total	99·17
Potassium chloride	traces		

The Wieliczka salt-mine, certainly the most celebrated in the world, is situate 9 miles from Cracow in Galicia, and has been worked for about 600 years. It is excavated in the ridge of hills at the N. extremity of the chain which joins the Carpathians. The salt is stoped out in longitudinal and transverse galleries, and large excavations are made in it, forming vaulted chambers of considerable height, and leaving massive pillars with arches between them for the support of the roof; but the work is more of the nature of quarrying than of mining. Explosives are not very generally employed in this or in many of the other salt-mines of the Carpathian district, the rock being cut out in square or longitudinal blocks. Grooves are cut about 25½ in. deep, forming the face of the rock into rectangular divisions; lumps are then broken off from the face of the rock by wedging, and these are further broken up into masses of ½–1½ cwt. for sale. The percentage of lumps to smalls produced by this method is stated to be as 75 to 25, the former selling for about 7*s.* a ton more than the latter. The lumps are generally sold just as they come from the mine, while the smalls are still further ground, and packed in sacks or casks; the scarcity of fuel precludes the possibility of dissolving and refining this salt, while its great purity admits of its easy sale in its natural state. The colour of the rock-salt forming the walls of this mine reminds one of a light-grey granite. The mine is divided into 4 levels or "fields," in the uppermost of which, 34 fathoms below the surface, the packing and preparation for transport is proceeded with. In the lower levels, the work of excavation is carried on; and on the second level, is a lake of fresh water derived from a small stream which flows over the top of the bed of salt, and is carried by wooden shoots to this spot. Many of the chambers in this mine are 80–100 ft. in height, and the excavations have been carried to a depth of no less than 783 ft., while many of the galleries are 1000 yd. long, and the total length of these galleries is about 30 English miles. The mines of Bochnia and Wieliczka together are, however, said only to yield 45,000 tons of salt per annum, the latter counting for 34,000. These mines give employment to 800–1000 miners and other persons. Many books of travel are replete with descriptions of this mine, but visitors who had read the accounts must have been frequently disappointed.

To add descriptions of other salt-mines would be mere repetition, the extraction of rock-salt differing in no respect from the getting of stone in any underground quarry, or the working of coal or similar stratified deposits. Foul air or explosive gases are not usually met with in salt-mines. In the Marston mine, however, after a shot had been fired on one occasion, there was a considerable evolution of marsh gas (methyl hydride), which took fire and burnt for some time, issuing from a blow-hole in the floor. E. Falk also met with a like evolution of inflammable gas in his mine at Winsford. In the strata above the salt in the Dax explorations, a disengagement of marsh gas took place during the sinking of a small shaft, and subsequently during some borings executed at about a mile distant. Some highly compressed pent-up gases, proved to be liquefied hydrocarbons, have likewise been found in small quantities in the rock-salt of Wieliczka and some other places, giving rise to small explosions when the rock is in course of being dissolved. Salt mines are as a rule perfectly dry, and the miners are usually healthy and subject to no special infirmities or inconveniences, unless it be some occasional slight annoyance from the irritating effects of the saline dust entering the throat, eyes, or nose. It is advisable when working a bed of rock-salt to leave a good thickness of the salt under the floor and in the roof, not trusting to the beds of clay with which rock-salt is usually interstratified, and which often exfoliate and give way. The pillars left for the support of the roof should be as large and massive as possible, in view of the possibility, however remote, of their becoming disintegrated and weakened, composed as they are of a soluble, more or less deliquescent material. When a rock-salt working is disposed to give way, cracks and fissures usually appear in the roof, and signs of crushing about the upper part of the pillars.

A process of cutting rock-salt by a stream of water, invented by an engineer named Pletsch, was employed till lately in the mines of Varengeville St. Nicolas, near Nancy. Fresh water, led through a pipe into the galleries of the mine, was there, from nozzles conveniently mounted on movable stands, caused to impinge in fine but forcible jets against the face of the rock. By this means, deep furrows were rapidly cut into the salt by solution, and large blocks could be detached with little manual labour and without blasting. This method, economical though it may appear, seems to have been the cause of a severe disaster in the mines in question. The salt was being worked in one of the lower beds (of which there are seven in all) where it was purest and of best quality, the cutting-water being permitted to run away to a still lower level in a channel cut in the underlying bed of clay, on which, in this case, the levels were driven. This water had a sp. gr. of not more than 1·52, and was consequently far from saturated; the purest portions of rock were therefore selected for sale as rock-salt, and the rest was broken up and used for further saturating the water of the reservoir below. The brine of the reservoir was finally pumped up to be evaporated for white salt. This plan of getting both brine and rock-salt was ingenious, and seemed to work successfully. The workmen, however, had long observed that the galleries of the mine seemed to fill up, by the swelling, as they supposed, of the clay floors, though in reality this was produced by the sinking of the pillars, probably from solution. One day the whole of this part of the mine suddenly fell in, and since then, the getting of rock-salt by this means has been abandoned. Since 1876, a salt-cutting machine has been introduced at Wieliczka with much success. It is constructed somewhat on the principle of Winstanley and Barker's coal-cutting machine. It would appear that in the course of 8 months' working, this machine has shown itself capable of cutting rock-salt horizontally at a rate of 59 sq. ft. per hour, or vertically to a height of 5 ft. 9 in. at a rate of 30–40 sq. ft. per hour. The average cost is stated to be about 21*s.* per cub. yd., as against 27*s.* for hand work. It is likewise stated that in working out the salt, this machine produces less smalls than hand labour, the proportion being only 17 per cent. The machines supplied by Stonek and Reska, of Prague, are made of steel in all their moving parts; they cost about 430*l.* each, and work by compressed air.

The annexed table shows the composition of the rock-salt of a few of the largest and best known mines of Europe. The Stassfurt salt, however, is not generally so impure as stated; in the Paris Exhibition of 1867, the writer obtained a sample from a lot of rock-salt from Stassfurt there exhibited in immense slabs and blocks, which gave on analysis no less than 99·95 per cent. of pure sodium chloride, and 0·05 of calcium sulphate, and was consequently nearly pure.

TABLE III. COMPOSITION OF ROCK-SALTS FROM WELL-KNOWN LOCALITIES.

COUNTRY.	Germany.								France.	Austria.		England.	
LOCALITY.	Schwabisch Hall, Wurtemburg.		Berchtesgaden, Bavaria.	Stassfurt, near Magdeburg.	Château Salins, Lorraine.	Vic, in German Lorraine.			Dax.	Hall.	Wieliczka, Galicia.	Rock-salt from Cheshire.	Do. from the Marston Mine, Northwich.
AUTHORITY.	Fehling.		Bischof.	Rammelsburg.	Mathieu de Dombasle.	Berthier.		Cordier.	Maxwell Lyte.	Bischof.	Bischof.	Richardson and Watts.	Crace Calvert.
Sodium chloride ..	99·97	98·81	99·85	94·57	97·05	99·30	97·80	97·45	96·97	99·43	100·00	98·30	96·70
Calcium chloride ..	..	0·02	trace.	..	..	..	..	..	..	0·25	..	..	0·68
Magnesium chloride	..	trace.	0·15	0·97	0·45	..	..	..	0·51	0·12	..	0·05	trace.
Potassium chloride ..	..	..	..	..	..	..	..	..	trace.	..	..	..	trace.
Calcium sulphate ..	0·02	0·11	..	0·89	1·50	0·50	0·30	0·25	0·23	0·20	..	1·65	0·25
Magnesium sulphate	..	..	..	..	trace.	..	..	2·30	..	..	..	..	..
Magnesium carbonate	..	0·15	..	..	..	..	..	..	..	..	..	..	..
Calcium carbonate ..	..	0·16	..	..	..	..	..	..	..	..	..	..	..
Ferric chloride	..	..	..	..	..	..	..	..	0·01	..	..	..	..
Clay or insoluble matters	0·01	0·80	..	3·35	..	0·20	1·90	..	2·28	..	..	..	1·74
Water or loss	..	..	..	0·22	1·00	..	..	..	..	..	..	..	0·63
Total	100·00	100·05	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

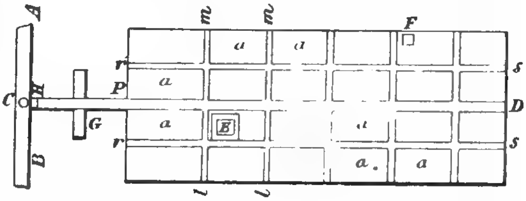
White Salt.—The third branch of the salt manufacture, viz. the production of white salt by the artificial evaporation of brine, is by far the most important of all the methods by which salt is prepared, so far as England is concerned, for not only is the salt thus obtained in a far purer condition than by any other method, but by this method we alone produce in the Cheshire and Worcestershire salt-works, probably as much as a third of the quantity of salt which is consumed in the whole of Europe.

The brine used in Cheshire is that alluded to as overlying the upper layer of the salt-measures, and it is raised by pumping, and fed into the various salt-works. Some of the salt-works raise brine for themselves by their own pumps, only paying a royalty to the landlord. The cost of the brine varies in the different districts: at Northwich, it is 4–9*d.* per ton of salt made; at Winsford, it is 6*d.*, and this latter price may be taken as a fair average. It is rare, however, to find saturated brine thus overlying the beds of salt. In other countries, this is seldom or never the case, and a description of the manufacture of white salt may be commenced by explaining the various methods used for obtaining the strong brine.

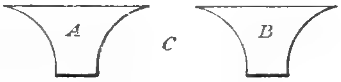
1. A shaft is sunk, and the rock-salt, mined in the usual manner, is brought to the surface and dissolved in water. Sea-water or the water of saline springs is sometimes used. In France, large wooden tubs called *bessoirs* are generally employed. The rock is broken and placed on perforated shelves, or hung in baskets round the upper edges of the tubs. The solution is performed in a reservoir of masonry or of concrete lined with cement, and in this case a sort of wicker boat is sometimes surrounded with empty casks to give it flotation, and laden internally with broken rock-salt, and floated on the water of the reservoir. The salt dissolves, the stronger brine falling to the bottom and the weaker rising to the surface, where it continually meets with fresh salt. The process thus continues, till, if the supply of rock be properly maintained, the whole bulk of the liquid speedily becomes saturated brine.

2. Another method employed, more particularly in working beds of saliferous clay, is the creation of a solution-chamber (*chambre de dissolution*) within the deposit itself (see Fig. 1205), into which water is introduced with certain precautions, and this, dissolving the salt, and becoming converted into brine, is pumped up for use. The construction of such a chamber is carried out in the following manner. A shaft E is sunk to the bed of salt or saliferous clay ; in this, a horizontal longitudinal gallery P D is first pierced, and from this, the transverse galleries *l m*, and other longitudinal galleries *r s*; this cuts the beds into squares or rectangles *a*, and these are further divided up by other smaller galleries, not shown, till the whole part to be excavated is cut into galleries, the roof being supported by the pillars left between. The size of the chamber, the distances separating the galleries, their height, &c., must depend on the nature of the ground, and in some degree on the fancy of the operator. By this means, is made a chamber of more or less rectangular form, the central gallery P D running throughout its entire length. Another transverse gallery A B is pierced in the same level, and at some yards distant from the end of the chamber, and the gallery P D is prolonged to meet A B at C. A long wooden pipe is laid from C to D, pierced with holes in its sides and bottom, and its upper part covered with a pent roof, so as to throw off any materials which may fall on it. A good timber dam is made at G, and well pugged with clay, and a sluice is made at H, by which the brine can be drawn off; F is another small shaft, through which water can flow into the chamber. The gallery A B may serve for any number of such chambers on the same level. All being thus arranged, water is allowed to flow down through F till the bases of the pillars are submerged a few inches. This water is soon converted into saturated brine; it is drawn off by opening the sluice H, and pumped to the surface. More fresh water is let in to a like depth, and finally the bases of the pillars get cut away by solution. Each time fresh water is let in, care is taken that it rises only just far enough to bathe the lower ends of the pillars, which are thus gradually dissolved upwards from their bases, the sides of the chamber becoming likewise excavated and enlarged by solution. This goes on until the pillars become completely dissolved, and the whole becomes one great chamber filled with salt water. Much care is to be observed in controlling the quantities of water fed into these chambers, in which the pressure should be maintained as moderate and unvarying as possible. The fresh water admitted, being lighter than the brine, has a tendency to rise to the surface, and the solution is liable to go on almost entirely at the top of the chamber, the interior of which tends to assume the form of an inverted cone from this cause. This involves loss, and where two or more chambers A B are being worked continuously, the erosion of the salt necessarily takes place in the form shown in Fig. 1206, the portion C remaining untouched. A partial remedy for this inconvenience, constituting the best mode of working, and now usually adopted, is to introduce the fresh water in a small but constant and steady stream at F (Fig. 1205), while the brine is being drawn off in the same continuous manner at H. This method of working saliferous clays is much used in Germany; at Dürrenberg, in Saxony, are 33 of these solution-chambers, each possessing a mean capacity of about 700,000 cub. ft.

1205.



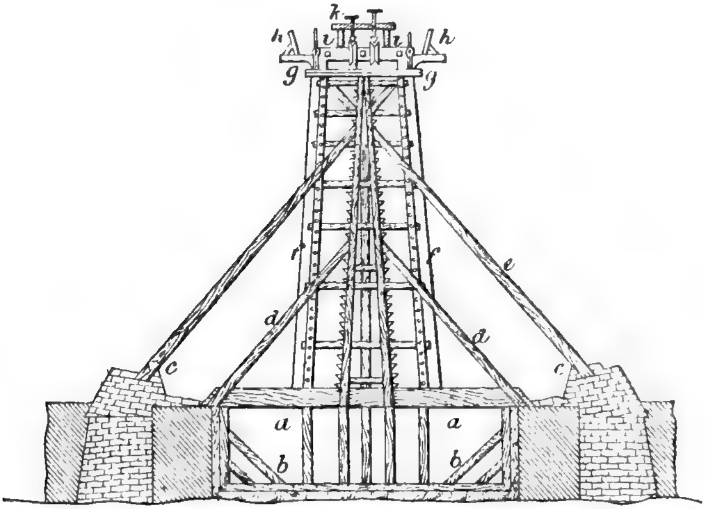
1206.



Another method of obtaining brine from a bed of rock-salt, and one frequently practised in France, is that of simply boring into the salt and letting fresh water run down the bore-hole, when it excavates a chamber for itself in the salt by solution, and may be pumped up again as saturated brine. The boring for this purpose has to be of a tolerably large diameter, say 8–10 in., and it must be tubed throughout with stout, well-riveted iron piping. Within this piping, descends the suction-pipe of a pump, this latter pipe being only 3½–4 in. diam.. and closed at the lower end, but having its sides pierced with numerous small holes for about 1–2 ft. from its lower extremity. A sufficient space is thus left between the two pipes for fresh water to find its way down to the bed of salt. It is usual to commence by sinking a well down to any water-bearing strata in the measures above the salt, and to commence the boring only from the bottom of this well; or a well is sunk alongside the boring. Fresh water from the upper strata or the surface is allowed to percolate from this well into the space between the tubing of the bore-hole and the suction-pipe of the pump, and to descend to the salt, where it becomes converted into brine, and may be pumped up. The establishment of a brine-chamber by this means is rather tedious, on account of the tendency of the fresh water to rise to the top, and erosion to take place only at the immediate surface of the salt, which thus gets eaten out just where it meets the superincumbent bed of clay, morsels of which detach themselves, and, falling into the bore-hole, are liable to choke the pump. A year or more may thus elapse before any steady supply of saturated brine can be pumped, much, however, depending on the nature of the bed immediately overlying the salt. If this be clay, much trouble and inconvenience may be experienced; whereas if a good firm bed of gypsum or anhydrite intervenes between the salt and the clay, as occurs in the districts of the Meurthe, all will be found to work successfully. Under these arrangements, the descending column of fresh water in the exterior pipe tending to counterbalance the ascendant column of brine in the suction-pipe of the pump to about $\frac{5}{6}$ of its height, the relative sp. grs. being as 1 to 1·20, the pump only has to do the work of elevating the brine through the remaining distance. Thus, with the bed of salt lying at a depth of 180 ft. from the level of the fresh water at the surface, the fresh-water column would tend to counterpoise and elevate the brine in the suction-pipe of the pump to a height of 150 ft., so that the pump itself would only have to lift or force the brine through the remaining 30 ft. In all cases, the brine when produced, whether by dissolving the rock-salt in tubs at the surface, or by extraction from the solution-chamber within the bed of salt itself, contains by far too much matter in suspension to be fit for immediate use. It is consequently allowed to clarify by subsidence in large reservoirs (*bessoirs*) prepared for its reception.

Sometimes the brine, whether derived from springs or otherwise, is not brought to the surface at a sufficient degree of concentration to be evaporated by artificial heat, without too great a consumption of fuel. It then becomes necessary to concentrate the brine. The most economical mode of doing this is obviously spontaneous evaporation by exposure to the air; and in places by the seaside where high winds prevail, and where land may be of but little value, large quantities of salt are economically produced, as already detailed, by this means. But in other places, this arrangement would be inconvenient, and other means of exposing the liquid to evaporation on an extended surface are resorted to. Such is the so-called "graduation" system invented by Abith in the 16th century, and still practised in a few places on the Continent. A graduation-house (*Gradishaus*) is generally a huge shed, 300–400 yd. long, presenting one end to the prevailing wind, and open at both ends. The interior is filled with rows of faggots; the floor is a large flat reservoir or basin, and on the top, by means of pumps and other arrangements, the water is sprinkled profusely over the faggots, and in course of descending into the trough below, trickles over the sticks, and exposes a large evaporating surface. By several repetitions of this process, the liquor loses water, and a concentrated brine is the result. Fig. 1207 represents the general construction of a graduation-house. A description of that at Schönebeck, one of the largest and most important establishments of this kind, will suffice, as the system is not required in England, and is becoming less used elsewhere. The building is 916 yd. long, and 11–14 yd. high. It is filled with a double tier of faggots, presenting a thickness of 5½–7½ yd. at its base, and 3¼–5½ yd. at the top, consequently offering an immense superficies for evaporation. The illustration shows the whole arrangement in profile, end on. *a* is the large reservoir for the salt water. It is excavated in the ground, and widens out at the top to *c* to catch any drip the wind may carry away; *d e* are merely stays to support the walls of the reservoir, and to sustain the building against the lateral pressure of the wind; *f* is the wooden framework in which may be arranged 4 vertical walls or tiers of faggots. These faggots are made of white- or black-thorn, the branches of which are especially crooked and angular. The water is elevated by pumping to the reservoir *h* at the top, which is so arranged that the outflow can be altered according to the way of the wind. The water is allowed to descend through two pipes, closed or opened at will by the valves *k*, into the transverse pipe *g*; thence it rises through the pipes, and flows out by cocks into pans, from the overflow of which it drips on to the faggots. Berthier calculates that the average evaporation in ordinary fine weather by this means at Moutiers, in Savoy, where cords are employed instead of faggots, the other general dispositions remaining the same, is 13⅕ gal. for every sq. ft. of cord surface in 24 hours. At Kissengen, the sheds are nearly 1¼ miles long by 25 ft. high. The water is raised six times in passing from one end to the other of the building, and by this, its strength is raised from 2½ to 17½ per cent. of salinity. Forbes has calculated that here nearly 3 million cub. ft. of water are evaporated annually by this means. The first set of faggots are stained brown by ferric oxide which encrusts them, and they all have to be changed every two years or so, on account of a deposit of calcium carbonate ("thornstone") which coats them. By whatever means the strong brine is obtained, it needs evaporation to produce white salt.

1207.



In England, as already stated, the brine comes up fit for use at once. In and around Winsford, are 35 salt-works, and 607 pans; in Northwich, 30 works, with about 485 pans; at Middlewich, 13 pans; at Sandbach, 68. At Droitwich are numerous works, mostly, however, on a smaller scale, with the exception of Chapel Bridge and Coverscroft. In Cheshire, the brine does not rise spontaneously to the surface in sufficient quantity to feed the works, but has to be extracted by pumping. It lies, as has been stated, on top of the rock-salts, on the corrugated surface of which it forms pools, or "runs," as they are often called. A shaft or well is sunk to the brine level, and the ingress of any fresh water from the overlying strata is guarded against by careful tubbing. The brine is then raised to the surface by means of pumps worked by steam power. The surface of the bed of salt is reached at a depth of about 40 yd., and the arrangements for the sinking and the pumping of the brine are so familiar as to need no description here. Suffice it to say that as brine exercises a solvent and corrosive effect on lead, and an oxidizing action upon iron, the use of either of these metals is to be avoided, either for the pipes or for the body of the pump itself; copper for the former and bronze for the latter are most to be recommended. Iron pipes are, however, usually employed in Cheshire and Worcestershire. Whole tree-trunks of elm or pine have been and are still occasionally employed, cut into short lengths, and joined together, and bored out as pipes, for conveying brine, and answer that purpose very well. In a few cases, the pump-shafts have been carried into old rock-salt mines, which have thus been utilized as solution-chambers, or reservoirs from which to pump brine. The strength of the brine obtained varies both with the locality and the season. The salt-makers say that the brine used in Cheshire contains about 2 lb. 10 oz. of salt per gal., but this is misleading. The writer is indebted to C. M. Blades, analytical chemist, of Northwich, for first drawing his attention to the following facts connected with this question. When salt was subject to a government duty, the excise officers were in the habit of estimating the strength of the brine by means of a "salinometer," a form of hydrometer graduated to indicate the amount of salt in lb. and oz. per gal., as shown at A, Fig. 1204. The old wine gallon then in use only contained 58,317 gr. of water, whereas the present imperial gallon weighs 70,000 gr.; but the salinometer used at that time is still retained by the manufacturers, while the new imperial gallon is the only one now recognized. The indications of this hydrometer are consequently misleading, and when, guided by this instrument, the manufacturer states that a brine of sp. gr. 1·204, and representing 26 per cent. of salt, contains 42 oz. or 2 lb. 10 oz. to the gal., his statement is erroneous. An imperial gallon of water weighing 70,000 gr. (10 lb.), an equal measure of brine of 26 per cent., and sp. gr. 1·204, should yield on evaporation 50 oz. (3 lb. 2 oz.) of dry salt, and this may perhaps be taken as an average strength for the brines of the Cheshire district. Misguiding as this may be, it has not so far led to any serious inconveniences, as the salt-makers usually purchase the brine from the owners of pumping-stations, paying on the amount of salt actually obtained. A change, however, in the mode of supplying brine is now taking place, and meters for registering the delivery are being introduced by several of the pumpers, with a view to check the enormous waste hitherto existing. In future, therefore, to avoid errors and simplify calculation, the present system of graduation of the salinometer will have to be altered. The French use the hydrometer of Baumé, or *pèse-sel*, which is constructed to indicate directly the percentage of salt in a given weight of brine, being graduated from 0 to 27. Twaddell's hydrometer indicates exactly oz. Av. of salt in the gal. of brine by the numbers engraved on its stem.

Otto Pohl found the average amount of salt in the Winsford brine to be 26·25–26·50 per cent. by weight, receding during rainy weather to 25. Thos. Ward states that the Cheshire brines usually contain about 25 per cent. (this is perhaps rather low for an average). As may be seen from the tables of solubility on p. 1711, the total solubility of pure sodium chloride in water at ordinary temperatures is about 27 per cent. The Cheshire brine may consequently be considered as a nearly but not quite saturated solution of common salt, especially when we remember that the small quantities of other salts present tend if anything to diminish the solubility of the sodium chloride. All natural brines employed in the manufacture of white or refined salt, whether derived from saline springs, from the concentration of sea-water, or by the direct solution of rock-salt, are contaminated with other saline constituents, of which the principal are magnesium chloride, and calcium sulphate; and it is a fact never to be lost sight of that all such brines, no matter what proportion of salt they may hold in solution, are as a rule saturated solutions of calcium sulphate. Were it not for the baneful presence of this calcium sulphate, and the pan incrustation chiefly due to it, the cost of producing white salt by artificial evaporation might probably be reduced by nearly one-third. Besides these salts, natural brines contain varying but small quantities of bromine, occasionally iodine, salts of potassium, and traces of iron, alumina, silica, boracic and phosphoric acids, &c. These other salts, however, interfere but little with the work of the salt-maker. In Cheshire, the brine is merely first pumped into reservoirs placed at such levels as to be able to feed the pans by an outflow-pipe. In these reservoirs, any insoluble suspended matter becomes deposited, and the brine then possesses a beautiful transparency, and a fine sea-green colour. In most of the Continental salt-works, the *bessoirs* already mentioned are employed. These require to be very carefully constructed, and are best arranged with external tie-rods armed with screws, so as to be able to tighten the joints from time to time.

In England, also, are wooden reservoirs for the brine in and about many of the salt-works, but they are usually fastened with tree-nails, and strengthened by stout timber ribs placed externally and very near each other, and the seams are kept tight by caulking; but they give endless trouble to keep them watertight. There is, however, probably far less loss under any circumstances from the wooden reservoirs than from those of puddled clay paved with stone generally used in Cheshire. The action of strong brine upon any wooden vessel in which it is stored, though highly preservative to the wood, is peculiarly astringent and contractile, and unless care be taken to provide against the emergency, it will be found that new wooden vessels, no matter how well made or how well the timber may have previously been seasoned, will not long stand the action of saturated brine, without requiring their joints to be tightened or caulked.

In cases where the brine is contaminated with any large quantities of magnesium salts, it is usual to decompose these in the *bessoirs* by an addition of milk of lime, the operation being called *chaulage.* The lime displaces the magnesium as a flocculent precipitate of hydrated magnesia, and decomposes at the same time any iron or aluminium salts, of which traces are usually present; it is added in just sufficient proportion for this purpose. As the precipitate accumulates in the *bessoirs*, they are cleaned out. The *chaulage* has been abandoned, except where necessity obliges it, for not only is the brine thereby made alkaline, and the crystallization rendered more difficult, but the liquor takes a long time to clarify, and during evaporation a crust is liable to form on the surface, which seriously interferes with the work. A far better plan is to wash away the magnesian salt, and other impurities that may be present, by a plentiful aspersion of the salt, after it has been made, with some saturated brine. In England, the brine as pumped and settled is sufficiently pure to be run at once in a continuous stream to the evaporating-pans, producing salt of superior quality, the mother-liquor hardly ever requiring to be run away till the pan is laid off for repairs (see Table opposite).

The nomenclature of the principal qualities of salt occurring in commerce may be stated as follows:—

Group I. Boiled.—Fine salt, sometimes called "lump" or "stoved lump"; superfine, also stoved; butter salt, not stoved; cheese salt, not stoved.

Group II. Not Boiled.—Common, fishery, extra fishery, double extra fishery, bay-salt.

In the French nomenclature, are *fin fin*, sometimes called *sel à la minute*, corresponding at the same time to our fine and butter salts; then 6-, 12-, 24-, 48-, 72-, and 96-hour salts, and another quality called *écailles*, a very coarse large grain, corresponding to bay-salt, chiefly made for sprinkling on the top of the salt fish in barrels.

The classification of the various qualities of salt varies with the size and appearance of its crystals, and these in their turn are almost entirely dependent on the rate at which the evaporation is carried on, and the greater or less degree in which the brine was agitated during that time. The boiled salts, produced during actual ebullition, and the liquid being frequently agitated, are fine in grain; the unboiled, produced by slower evaporation, are of coarser grain, according to the temperature, the time expended in their production, and the stillness of the brine during that process. The evaporating-pans are built of common boiler-plate, ¼–⅜ in. thick, the plates being about 4 ft. long by 2 ft. wide, and well riveted together. The plates are usually of rather smaller dimensions in the part immediately over the fire than elsewhere on the bottom or floor of the pan, as by this means some of the tendency to warp and buckle is supposed to be avoided. In England, the usual dimensions for fine and extra-fine salt-pans are 30 ft. long by 22–25 ft. wide, and 1 ft. 9 in. deep. This gives an evaporating surface of 720–750 sq. ft. Butter-salt pans are perhaps a trifle longer, say 35 ft. by 22–25 ft., and the same depth, with an evaporating surface of 770–875 sq. ft. Common and fishery pans range from 50 to 70 by 22–25 ft., and have the same depth, presenting an evaporating surface of 1100–1750 sq. ft.; some fishery salt-pans belonging to the British Salt Co. at Anderton are 90 ft. by 22, while at Stoke and Winsford, are fishery salt-pans ranging up to 130 ft. in length. Beyond 70 ft. in length, however, there really would not seem to be sufficient gain, at least with the quality of fuel used in Cheshire, to compensate the increased cost of construction and repairs. In France, the common and fishery salt-pans are about the same sizes as ours, only perhaps a trifle wider; and at Dombasle, near Nancy, where the intelligent manager Botta has carried the manufacture to as great perfection as is attained in perhaps any works, the pans (*poêles*) are 72 ft. by 29½ ft. by 43½ in., with an evaporating surface of 2124 sq. ft.

TABLE IV. ANALYSES OF BRINES.

AUTHORITY.	A. B. Northcote.				Heine.		Fehling.				Maxwell Lyte.
	Cheshire.		Worcestershire.		Schönebeck.						
LOCALITY.	Marston.	Wenlock.	Droitwich.	Stoke Prior.	Before Graduation.	After Graduation.	Clemenhall.	Sulz.	Friedrichshall, Wurtemburg.	New York, Salina from the Carboniferous Formations.	Dax, in the South of France.
CONSTITUENTS.											
Sodium chloride ..	25·222	25·333	22·452	25·492	10·404	25·160	25·902	23·473	25·563	13·239	25·273
Magnesium „ ..	..	0·171	..	..	0·073	0·630	Traces	..	0·006	0·046	0·030
Calcium „ ..	..	..	..	..	..	..	..	..	..	0·083	0·106
Sodium bromide ..	0·011	0·020	Traces	Traces	..	..	..	..	..	..	0·016
Sodium iodide ..	..	..	..	..	..	..	..	..	..	..	..
Sodium sulphate..	0·146	..	0·390	0·594	..	..	0·019	..	..	..	..
Potassium „ ..	Traces	Traces	Traces	Traces	0·148	0·550	..	..	..	..	..
Magnesium „ ..	..	..	..	..	..	0·130	0·610	..	0·002	..	..
Calcium „ ..	0·391	0·418	0·387	0·261	0·281	0·170	0·444	0·508	0·437	0·569	0·357
Sodium carbonate	0·036	..	0·115	0·016	..	..	..	..	..	..	..
Calcium „ ..	..	0·052	..	..	0·049	..	0·019	0·016	0·010	0·014	0·015
Ferric oxide and alumina ..	..	..	..	..	..	..	..	..	..	0·002	0·012
Silica	..	..	..	..	..	..	..	..	..	..	0·005
Water	..	..	..	..	..	..	73·615	..	73·982	..	..

In this table, the presence of calcium chloride in the Dax brine, of the sodium sulphate in the Worcestershire brine, and the large proportion of potassium sulphate in the Schönebeck brine, are specially to be noticed. It is stated by the salt-makers of Cheshire that the Worcestershire brine works far more easily than theirs. If such be the case, it may be attributable to this peculiarity of composition.

The floor of a pan is usually made slightly arched upwards towards the centre, so that a new pan is rather deeper at its sides than in the middle; but they soon flatten out and warp in various directions under the influence of the firing. On the Continent, cast-iron pans have been in some cases adopted, and cast-iron plates substituted for the smaller wrought-iron ones universally employed in this country in the part of the pan just over the fires. Besides the advantage accruing from the less tendency to buckle and warp, the cast-iron has a much higher conductive power than the wrought-iron, and the advantage of cheapness. The plates are not made much thicker than the ordinary wrought plates, and are cast with exterior flanges all round their edges, by which they can be bolted together beneath the pan. They also have grooves cast in their edges, to receive asbestos cord or cement, by which, when screwed up, they can be made watertight. Were it not for fear of their greater fragility and some difficulties of adjustment, they would doubtless be employed in this country, thus avoiding leakages into the flues, and the consequent production of large stalactites of salt, technically termed "cats," an intolerable nuisance to the salt-maker. In Austria, such cast-iron pans are actually now in use, and their advantages will be manifest from the following comparative experiments made at Berchtesgaden under like conditions of firing, &c.:—

	Temperature attained in the pan.	Cost of maintenance. £	Durability.
Sheet-iron	64·4° F.	74·8	12 years.
Cast-iron	75·2° F.	34·4	21 years.

It is also sometimes the practice abroad to make the pans with plates riveted on to T-iron bars running across the width of the entire pan, the central flange of the T-iron standing up between the edges of the plates, and these latter having the rivets countersunk into them. This seems somewhat to prevent the buckling.

1208.

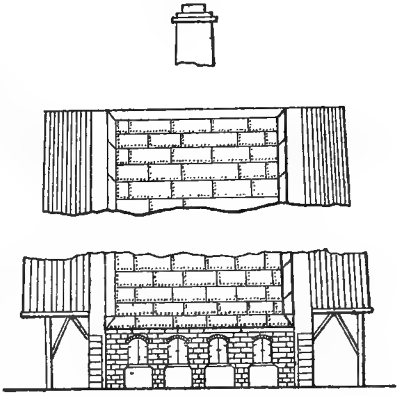
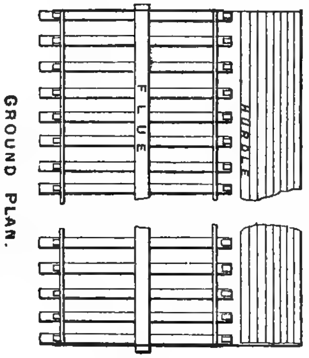


Fig. 1208 represents the usual mode of setting pans in Cheshire, the two ends only being given, showing the positions of the chimney and the fires. This may be taken as illustrating any of the ordinary pans, whether for boiled or unboiled salts, the sole difference consisting in the respective lengths of the pans.

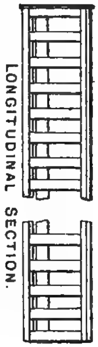
Wooden pans even have been and still are employed. One belonging to Thompson, of Northwich, is 4 ft. 6 in. deep, 12 ft. wide, and 75 ft. long. The two ends are of sheet-iron, and a long sheet-iron cylinder, closed at the two ends by steam-tight doors, runs from end to end. This cylinder is about 18 in. diam., and is supplied from above at about the middle of the pan by means of a lateral pipe with waste steam from an engine and boiler near. By this, the pan is kept at a temperature of about 90°–100° F. This pan is said to produce 45–50 tons of extra fishery salt every 6 weeks or so. Figs. 1209–11 represent such a pan, of which there are several at Northwich, in plan and in longitudinal and transverse sections, as well as the house containing it.

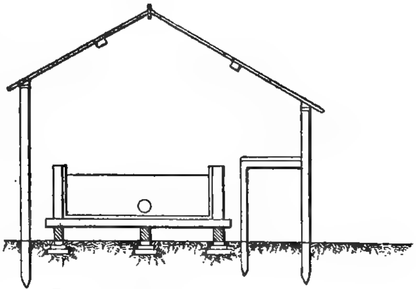
In Cheshire and Worcestershire, the fire-places, usually 4 in number, measure about 4–5 ft. from the door to the back, and are about 3½–4 ft. wide; from the bottom of the pan to the grate-bars is usually about 3 ft. In the case of very long pans, this height may increase to 3 ft. 4–5 in. The grates are formed of square wrought-iron bars, it being found inconvenient in salt-works to employ the improved cast-iron "fishbellied" bars. This is on account of the great liability to choking with clinkers, and caking of the ashes with the brine which drips from leaks over the fires fusing into clinker, and clogging the grate-bars. The blows necessary to detach these masses would seriously endanger cast-iron bars; but certainly the shape of the bars might well be improved, and rocking-bars, such as those employed in pyrites-kilns and elsewhere, might be more generally introduced with advantage. The firing is usually done in a stoke-hole with steps on each side leading up to the pathway around the pan.

1209.



1210.





TRANSVERSE SECTION.

1211.

In France, often 2 fires only are put under each pan. The general construction of a French salt-works is rather more regular than in those of this country, and the pans are usually placed side by side in sheds, while a common flue connects with the outlet-flue of each pan, and such arrangements are made that, when required, any one pan can be cut off by a damper. This common flue is made to pass beneath one or more long deep pans fed with cold brine, and from these the brine is fed, already more or less warmed, into the evaporating-pans. English pans are always set on brick-work, and their bottoms stand about on a level with the ground, overlapping their sustaining walls by some inches, and reposing on longitudinal flues. These latter are usually 4, corresponding in number with the fires, and run straight nearly the whole length of the pan, sometimes entering a chamber at the far end, and passing thence to a low chimney serving one or two pans; but sometimes they converge simply into one common flue, running the whole length of a row of pans, and having an exit to the main chimney. At times the flues do not continue the whole length of the pan, which is then supported here and there by pillars or bits of wall built in parallel lines. Sometimes no flues at all are employed, the pan being merely sustained by pillars of brickwork, sandstone, or cast-iron. The whole space then beneath the pan constitutes one large flat flue, through which the heated gases find their way unencumbered. This plan is common in Worcestershire.

On the Continent, other dispositions of flues are often adopted. At Nancy, and pretty well throughout France, the flues from each fire (often only two) run down to the end of the pan, returning towards the fire-end, and back again once more to the chimney or main flue, each flue thus forming 3 parallel lines. This plan has been tried in England, but is not now usually employed, the simpler form of straight flues leading from each fire right away to the chimney or common flue seeming generally to be preferred. Here in England also they usually have two "dead" flues, as they call them, one on each side beneath the pan, these being spaces like flues, but completely walled up at each end, so that no gases can enter them, as shown in Fig. 1225, p. 1739. This represents the arrangement of flues now generally adopted. The flues are usually 2–3 ft. deep, of a capacity in fact to admit a man or boy; and between the entrance of the flues and the fire-place, is built a wall of fire-brick, reaching to within 18 in. of the bottom of the pan. Over this "bridge," as it is called, the heated gases pass before entering the flue, and as the bricks of the bridge become red-hot, they tend to induce a more perfect combustion of the smoke before it enters the flues, where it would become too rapidly cooled by contact with the bottom of the pan, and soot would fall.

In Cheshire, and other places in England, the evaporating-pans are at times employed quite open and exposed to the sky, but nowadays they are mostly surrounded with sheds, these being furnished with ventilating openings in the roof, to facilitate the escape of steam. On the Continent, all except the fine and butter-salt pans are generally covered in with wooden trunks, flat on top with sides converging upwards, thus forming an elongated truncated cone about 5 ft. high over the pan. All along the lower parts of the sloping sides of this cover, and on both flanks of it, are frames fitted with shutters removable by hand. By removing one or other of these, the progress of the crystallization may be watched. A shelf is sometimes made, running along the whole length of this cover of the pan, just above the shutters; and when the pan is drawn, the workmen fish out the salt with rakes and scoops, and let it drain a bit on the drainers alongside of the pan, corresponding to what our salt-makers call "hurdles," and then pitch it overhead on to this shelf, on which it is allowed to drain pretty completely, the drippings falling back into the pan; thence it is shovelled on to the flat top of the cover of the pan, which is set with tiles. On these tiles, which are kept hot by the steam within the trunk during the time the pan is at work, the salt becomes dried, and is then on a level with the bins (*magasins*) into which it is tipped from waggons for storage. From that end of the trunk furthest removed from the fires, rises a wooden chimney 10–15 ft. high, for carrying off the steam from each pan; it passes through the roof of the building in which the work is carried on. Sometimes fan-blowers are placed in this and the main chimney, to expedite the exit of the steam. It is asserted by many of the French salt-makers that notwithstanding the greater cost of covering in the pans in this manner, the lessened facility of egress for the steam, the inconvenience, and the somewhat larger amount of labour involved in drawing the pans, they are compensated by a considerable economy in the combustible employed, through the diminished loss of heat by radiation; certainly they obtain cleaner products than English salt-makers. At the Dombasle salt-works, one of the best-managed and best-organized in France, the writer has, on the contrary, noted that with 100 *kilo.* of the small, poor coal from Saarbrück they only produce 160–170 *kilo.* of common salt. This coal is, however, far inferior to the slack used in Cheshire and Worcestershire, and it is not employed for fine or butter-salt, being unable to maintain a pan in continued ebullition, so small is its heating power. It is used on account of its low price, and its yielding a gentle diffused heat suitable for the work.

The stoves in which "lumps" of fine salt are dried in England are low rooms usually placed at the ends of the butter and fine salt-pans. Through these pass the flues conveying the still heated gases to the chimney. The gases from the boiling pans are employed by preference, as they emerge at a higher temperature than from the non-boiling pans, and the flues conveying them become very strongly heated. Sometimes these flues are carried below the ground, sometimes above, the intervals between them being then termed "ditches." In either case, the flues are covered with cast-iron plates, and are made to wind about in the stove-room, so as to present a considerable radiating surface. The temperature of these rooms is usually 49°–65½° (120–150° F.), often even higher. The floor of the room and the iron plates covering the flues are bestrewn with common white or ground rock-salt, to an inch or two in depth, and this forms a warm, dry, and absorbent bed of material on which the lumps of salt rapidly become dried. Their dryness is recognizable by their peculiar ring on being struck, as compared with the duller sound they emit while at all moist.

Manufacture of Boiled Salts.—For fine, superfine, butter-, and cheese-salts, the pan employed is not more than 30–35 ft. long, sometimes as low as 25–26 ft., by 22–25 ft. wide. The salt is fished out of these pans twice each day, perhaps a little oftener for butter-salt, and the pans have to be laid off and scaled every month, or even oftener. These boiled salts are all fine-grained, some rather finer than others. This fineness is obtained by keeping the brine not only boiling, but well agitated by raking. Superfine salt is but the same rather more carefully made, and subsequently ground. Butter- and cheese-salts, which hardly differ from each other, are not stoved. The salt from the boiled-salt pans is drawn to the sides of the pan by iron rakes, when it is lifted out of the brine by means of perforated shovels, called "scoops," the ends of which are turned up for this purpose, as shown at C, Fig. 1204. Two forms of drainers are used in Cheshire, one conical, called a round tub or basket, the other, already mentioned, called a square tub. The former vary rather in capacity, but usually they are about 3 ft. from the brim to the end of the foot. Square tubs are 18 in. long by 7 in. sq. at one end and 9 in. sq. at the other end, consequently they form truncated quadrilateral cones. Their bottoms are removable. For the purpose of filling, the round tubs are ranged, standing on their pointed ends in the brine, around the inner sides of the pan, and as the salt is fished up, they are filled with it one after the other. The square tubs are filled in the same manner, only where these are used, the pan is surrounded with a sort of gallery or platform of bar-iron, on the inside, just barely below the surface of the brine, on which the tubs are placed to be filled. They are then carried to the stove-room, where they are inverted, and the shapes of salt are turned out and left to dry. When the lumps made in the square tubs are dry, about 80–84 of them go to the ton.

When a pan of any of the boiled salts is to be started, the brine is run in, and some gelatine, glue, or sometimes blood, is added, while the fires are urged till the brine boils. A scum rises to the surface as the heating proceeds; this is removed, and the brine, from having appeared at the first heating rather opalescent, becomes clearer, while the bottom of the pan gets whitened with an incrustation, particularly at first just over the fires. At the same time, if the brine is strong and good, there tends to form all over its surface a crystalline pellicle or crust. If fine salt is being made, this is broken down by striking the water with a flat piece of wood from time to time; but when the boiling commences, this pellicle breaks up as fast as it forms, and the floating bits of salt drift from the fire end of the pan towards the other, where they sink and accumulate. This operation goes on continuously, and the salt by this means falls down during the whole boiling in largest quantity at the end of the pan farthest from the fires, and when enough salt has accumulated to make it worth while, the pan is drawn. This is under ordinary circumstances about twice a day; for butter-salt, perhaps a little less often. A pan of 33 ft. by 24 ft., which may be recommended as a convenient size for boiling, ought to yield 5–6 tons of salt per 24 hours, making 30–35 tons a week. But including stoppages for scaling and repairs, and taking into account the diminished yield when the pan gets very thickly encrusted, the real yield can hardly be reckoned at over 25 tons a week. The process is continuous, brine being run in as fast as the evaporation proceeds, the pan being thus always maintained about three-quarters full. The scale which forms on these pans is usually very thick, and contains a very large proportion of mechanically combined salt. This kind of scale is called "salt-scale," in contradistinction to that which forms on the unboiled pan, called "pan-scale" or "sand-scale," and which differs essentially from it in composition. Analyses of samples taken from the works of Thos. Ward and Messrs. Gibson will be found in Table V., p. 1733. Several inches of this scale will sometimes form in the course of a week in these boiled-salt pans, and, as may well be supposed, most seriously diminishes the evaporative duty of the coal. The fine and butter-salt pans are usually scaled once a week, and require very frequent repairing. For this purpose, the fires are extinguished, and the pans emptied of their brine, which is usually run to waste, when workmen enter, break up and chip off the scale with picks, and shovel it away. Attempts have been made to do this scaling without emptying the pan, and at the Stoke works near Droitwich, this work is performed every two days by a man wading about with his feet in two wooden buckets. This is a decided advance on the method usually employed. The boiled-salt pans are liable to a sort of efflorescence of salt over their edges, which is cut off from time to time, and which, if not removed, would often siphon the brine to a considerable extent out of the pan by capillarity. These cuttings are sold for use in agriculture under the name of "claggings," and the salt-scale is at times ground and sold for the same purpose. The latter has also been employed in making coarse glass, and some is at present sold for fluxing purposes in metallurgical operations. It will be necessary to return to these boiled salts when considering machine and composite pans, and the Otto Pohl process.

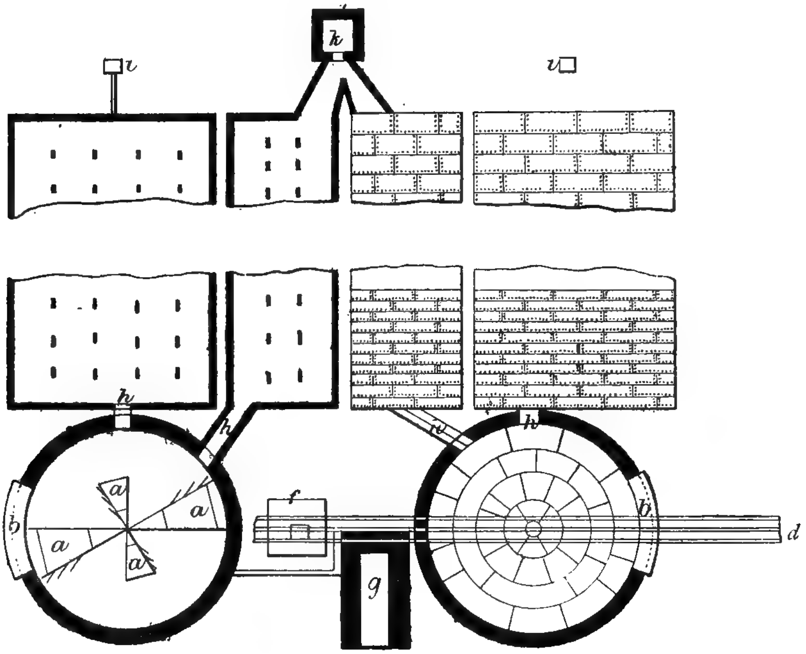
Manufacture of Unboiled Salts.—The various qualities, which only differ from one another in the size of the grain and their more or less perfect crystallization, depend for their production on the slow evaporation of the brine at temperatures far removed from boiling. They include the so-called "common" salt, the different qualities of "fishery-salt," and that known as "bay-salt." Whereas the length of the pans in which the boiled salts are made is limited to 35 ft. at the outside, it being impossible to keep longer pans in a constant state of ebullition without such fierce firing as would destroy them; on the other hand, in the manufacture of the coarser-grained unboiled salts, the length of the pans is increased till all chance of boiling is avoided, while a greater economy of fuel is attained. When a pan of cold brine begins to be fired, that part of the brine immediately over the fires naturally first takes the heat, and, growing lighter by expansion, rises to the surface, the colder brine from the further part of the pan running in from below to take its place; the warm brine, then gradually diffusing itself on the surface, goes to the far end of the pan, where, cooling by evaporation or by contact with the other cold brine, it sinks, returning to the hot end of the pan to become once more heated. Thus is established a circulatory movement in the brine, a supernatant current of warm liquid flowing from the fire-end, and a cooler current always flowing back below; this continues so long as the brine is kept only gently heated and is not actually boiled. As soon as any excess of water the brine may have contained has become dissipated, the salt begins to form, producing the "hopper-crystals" already mentioned; while a crystalline crust collects on the surface, and drifts towards the further end of the pan, there sinking to the bottom. To avoid too much salt thus drifting to the far end of the pan and filling that part too rapidly, thin narrow laths of wood are stretched across the surface of the brine, which stop these floating crystals and cause them to fall down. When a pan is first set down, it is customary to add 2–12 lb. of alum for a pan three-quarters full of brine. Alum is particularly used in this way in making fishery-salt. The brine is first made to boil, or very nearly so; the fires are then damped down a little, and the temperature is thus maintained and the evaporation allowed to proceed at a lower point, according to the quality of salt required. About 180° F. (224° F. being the temperature at which saturated brine boils) is the temperature for common salt. On the first heating, a scum rises to the surface, as in the case of the boiled salts. This scum is mostly due to the alum, which is decomposed, and the alumina comes to the surface, carrying with it any suspended insoluble matters, and perhaps taking up organic impurities the brine may contain. As previously stated, most brines (those of Cheshire form no exception) are saturated solutions of calcium sulphate, as well as of sodium chloride; and calcium sulphate is one of the few salts known to be *less* soluble in hot than in cold water. The consequence is that the brine, besides containing some trifling particles of suspended matter, becomes more or less clouded by a deposit of calcium sulphate, possibly also by a little calcium carbonate when first strongly heated. This either falls down as incrustation, or rises to the surface in the scum, and thus the liquor, which had become a trifle turbid, again clears. Alum is also occasionally, but not so often, used in this way for butter-salt, and at times, in the case of boiled salts, a small lump of butter or grease is added; this has a tendency to break up and throw down the crystals. These are among the supposed secrets of the salt-makers, and the substances thus added are termed by them "poisons." The scale from unboiled pans differs considerably in composition from that formed in the boiled pans, as shown by the annexed table :—

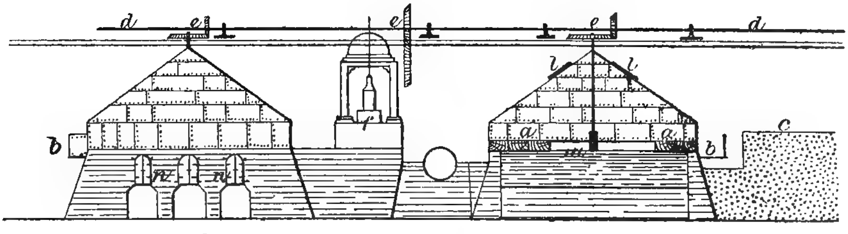
TABLE V. ANALYSES OF PAN-SCALES.

LOCALITY.	Turrenburg.	Anderton, near Northwich.	Dax, South of France.	Verdin's Works at Winsford.		
	From Unboiled Pans.				Boiled Pans.	
AUTHORITY.	Heine.	Tookey.	Maxwell-Lyte.	Maxwell-Lyte.	Tookey.	Maxwell-Lyte.
COMPOSITION.						
Sodium chloride	10·77	0·14	0·19	0·07	90·62	87·02
Sodium sulphate	9·05	..	4·30	..	..	..
Potassium ,, ...	1·02	..	traces	traces	..	..
Magnesium ,, ...	0·43	..	..	..	..	..
Calcium ,, ...	71·94	83·00	82·26	87·00	8·02	9·86
Magnesium carbonate ..	0·21	..	0·30	0·10	traces	0·05
Calcium ,, ..	0·09	1·07	2·79	0·27	0·25	0·30
Ferric oxide and alumina	0·13	traces	1·53	0·52	traces	0·30
Silica	0·15	..	0·28	0·37	..	..
Water	6·19	15·65	5·21	11·67	0·90	1·97
Totals	99·98	99·96	99·86	100·01	99·79	99·50

To fill a pan with salt, the brine being allowed to flow in a small gentle stream in quantity sufficient to replace that lost by evaporation, takes, in the case of common salt, working at a temperature of 71°–82° (160°–180° F.), 48 hours; common or Scotch fishery salt, working at 54°–71° (130°–160° F.), 4–5 days; extra fishery, working at 38°–43° (100°–110° F.) and in long pans, 7–8 days; double-extra fishery, working at about 32° (90° F.), 10–14 days; large-grained bay-salt, working at 24°–27° (75°–80° F.), 3–4 weeks. The "wych-house," as the wooden shed is called in which the evaporation is carried on, is 15–18 ft. wider than the pan itself; on each side of it, abutting against its walls, are low shelves of boards, placed near the ground, sloping gently inwards, and running the entire length of the pan, though separated from it by a pathway in which the workmen can circulate. On to this shelf the salt is thrown to drain, one workman drawing it to the side of the pan with a rake, while another fishes it out with a scoop or skimmer. The men who work at the drawing of the pans are called in Cheshire "wallers," and the boards on to which it is thrown are called "hurdles." These latter (Figs. 1208–9) are 5–6 ft. wide. The salt is taken from them in wheelbarrows or trucks to the store by men termed "lofters." In England, it is generally managed, if possible, to place the wych-houses on a higher level than the store, so that the salt when wheeled there may be tipped from above into the bins reserved for each kind; but in France, the construction of a salt-works to meet the requirements of the excise will rarely permit of this, so the pans and the bins into which the salt is tipped are put on about the same level, the salt being lifted from the hurdles to the tops of the covers (*hottes*) of the pans, on which it is dried before storage, instead of being merely drained on the hurdles as in England. This mode of treatment depends on the heavy tax (125 *fr.* or 5*l.* a ton) levied on all salt for domestic purposes in France, chemical and agricultural salts being alone exempted. Two excisemen are attached to and obliged to live in every French salt-works, while the works are compulsorily surrounded completely by a wooden palisade about 7 ft. high and reaching the ground, the laths of which must not be over ⅜ in. apart. There must be likewise but one gateway to the works. The result of drying the salt before placing it in the bins is that these French salts nearly always gain rather than lose weight in transport, attracting more or less moisture from the atmosphere; and being always in sacks, the

1212.





1213. 1214.

purchaser feels that even if he has to pay a heavy tax, he gets good weight for his money, while the salt-maker pays his tax on the lowest weight possible. The tax in France has likewise tended generally to make the manufacturers (*saulniers*) careful to produce the finest and purest article practicable. They have likewise protected themselves by syndicates in the respective districts, so as to ensure against over-production, and they have thus succeeded in maintaining prices at remunerative rates. Further, as the tax is often only made payable 4–5 months after the salt has left the works, though sales are effected at short dates of payment, large sums constantly lie in the hands of the manufacturers, and more than suffice to form their floating capital.

The quantities of coal used in the manufacture of salt vary according to the kinds of salt, and also somewhat in the different works. The boiled salts take the most coal, as the gases leave the pans at high temperatures. Common salt is about the most economical of fuel, the different fishery-salts and bay-salt occupying positions intermediate in this respect between the two. Fine salt takes about 13 cwt. per ton of salt; part of this heating power goes to maintain the temperature of the stoving-room. Common salt should take but 9 cwt. of coal per ton of salt. The fuel used in the Cheshire salt-works is the small coal called "slack" from Lancashire and Staffordshire; and "burgey," i. e. small and large mixed just as they come from the mine, mixed with the slack or by itself, is often used for boiled salts. Small coal is preferable for producing the mild heat required in salt-making, and has the further advantage of cheapness.

The annexed tables, giving the analyses of some British and foreign white salts, will be of interest:—

TABLE VI. ANALYSES OF COMMERCIAL WHITE SALTS.

AUTHORITIES.	Henry.	Ure.	Watts.		Richardson and Watts.	Fehling.		Maxwell Lyte.	Crace Calvert.	Maxwell Lyte.	Virch.		Heine.
LOCALITY.	Cheshire, Fishery dried at 212° F.	Cheshire, Stoved.	Schönebeck.	Stassfurt.	Spencer, New York.	Wilhelms-Gluck.	Friedrichshall, Butter Salt.	Dax, Common Salt.	Cheshire, Agricultural Salt.	Machine Pan Butter Salt from Winsford.	Seelz, in Mecklenburg, Butter Salt.	Ditto, ditto, Common Salt.	Artern.
CONSTITUENTS.													
Sodium chloride ..	98·60	98·250	95·402	97·094	96·29	98·900	97·550	98·500	95·82	95·272	93·79	90·75	96·53
Potassium „ ..	..	..	..	..	Trace	..	..	..	..	..	0·89	1·00	..
Calcium „ ..	..	0·025	..	0·345	Trace	..	..	0·010	Trace	..	0·26	0·99	..
Magnesium „ ..	1·10	0·075	0·800	..	0·27	..	..	0·037	..	0·014	0·14	0·60	..
Sodium sulphate ..	..	..	..	..	Trace	0·005	..	..	..	..	..	..	0·96
Potassium „ ..	..	..	0·414	0·390	..	..	..	..	..	..	..	..	..
Calcium „ ..	1·20	1·550	0·732	0·727	1·39	0·498	0·934	0·452	..	1·900	1·44	0·59	0·64
Magnesium „ ..	..	..	0·471	0·180	..	..	0·009	..	..	..	..	..	..
Ferric oxide and alumina ..	..	..	..	..	0·25	..	..	0·090	..	0·160	..	..	..
Insoluble matter ..	0·10	..	..	..	0·03	..	..	..	..	0·041	..	..	..
Calcium carbonate	..	..	..	..	..	0·005	0·016	..	..	..	..	..	..
Water	..	..	2·901	1·264	2·20	0·602	1·488	1·890	4·18	2·605	3·88	6·48	1·86
Total ..	101·00	99·890	99·920	100·001	99·23	100·010	99·997	99·889	100·00	99·992	..	.	..

TABLE VII. ANALYSES OF AMERICAN AND ENGLISH SALTS—(Porter and Goessman).

LOCALITY.	AMERICAN.									ENGLISH.			
	Onondaga.	Hocking Valley.	Mason City.	Onondaga.	Turk's Island.	Onondaga.		Ashton.		Stubbs.	Ashton, North-wich.	Deakin.	Marshall.
	Fine Boiled Salts.			Coarse Salts.		Dairy Salt.							
CONSTITUENTS.													
Sodium chloride ..	97·12	93·26	95·77	97·31	96·76	97·760	97·672	97·59	97·660	98·0229	97·7598	97·4728	98·4065
Calcium „ ..	0·15	1·43	0·61	0·05	..	..	..	0·01	..	..	..	..	..
Magnesium „ ..	0·13	0·70	0·04	0·05	0·14	..	..	0·03	0·059	0·0124	0·0591	0·0353	..
Sodium sulphate ..	..	..	..	..	0·64	0·025	0·008	..	..	..	..	..	0·1135
Calcium „ ..	1·33	..	..	1·05	1·56	1·295	1·235	1·67	1·381	1·3798	1·2272	1·4413	0·8888
Magnesium „	..	..	..	..	..	0·066	0·082	..	..	0·0817	0·0769	..	0·0281
Insoluble matter ..	..	0·01	0·11	..	..	0·130	0·124	..	..	0·0616	0·0564	0·0490	0·0500
Water	1·27	4·60	3·47	1·54	0·90	0·724	0·879	0·70	0·900	0·5620	0·7880	0·9520	0·4940
Total	100·00	100·00	100·00	100·00	100·00	100·000	100·000	100·00	100·000	100·1204	99·9674	100·0757	99·9809

With regard to Tables VI. and VII., it is to be noted that samples taken fresh from the bins generally contain more water than shown in the analyses, unless the salt has been dried before storage. The water usually amounts to 3–4 per cent. for butter-salt, 5–6 for common salt, and 7–8 for fishery-salts, while some extra fishery-salts contain even more. This water, however, being for the most part merely mechanically held between the crystals, drains away during transit or long storage.

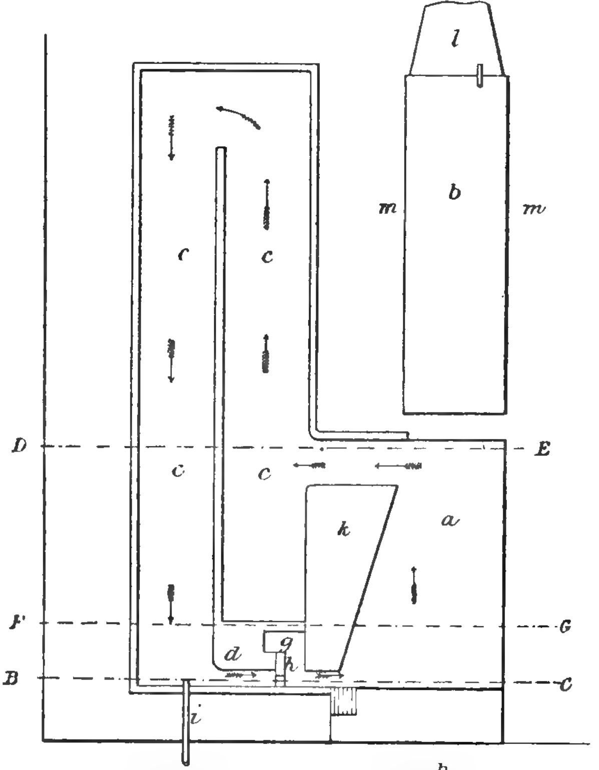
The innovations introduced of late years in the salt manufacture require to be shortly alluded to. Both in England and abroad, attempts have been made to reduce the loss of heat, chiefly due to the scale in the pans and the soot of the flues, by heating by steam. Whatever economy there may be in this method, it has not made much progress among English salt-makers, though the system is a common one for other purposes in the salt districts. The steam-pipes get covered with scale, which is difficult to detach without injury to them, and they are rather in the way of drawing the pans.

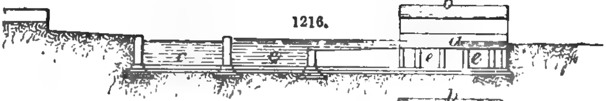
So-called "machine-pans" are employed at the works of Verdin, Falk, and the British Salt Co., and probably elsewhere. These are round pans, Figs. 1212–4. They are usually worked in pairs, standing 20–30 ft. apart, with a small engine *f* between, or a shafting *d* running above several of them driven by an engine at one end; this shafting is geared by bevel-wheels *e* to the stirrers *a*, and is so arranged that any one or more of the pans can be thrown into or out of gear at will. The depth of the pans is 2 ft., and an opening is left in one side of each down to the bottom, this opening being closed with outside troughs *b* riveted to the sides of the pans. The bottoms of these troughs go lower than the bottoms of the pans, so that any salt swept out of the openings falls into the troughs, and cannot return into the pans. The pans are fitted with conical covers of sheet-iron, through the centre of which pass iron spindles, geared above to the pinions of the shafting by bevel-wheels, and resting on the bottoms of the pans, in which they are free to turn. These spindles are attached at their lower parts to the arms or stirrers *a* carrying scrapers swinging loosely beneath them, and resting on the bottoms of the pans. The covers are fitted steam-tight upon the tops of the pans, and each is provided with one or more manholes *l*, by which workmen can enter to clean the pans. Those parts of each cover corresponding to the parts left open in the sides of the pans are brought down so as to partially close the openings and come just low enough to dip into the brine about 2 in., when the pans are about ¾ filled, while the spindles passing through the covers turn in stuffing-boxes. Thus, when the pans are closed, they are steam-tight, and there is no exit for the steam unless by forcing the water out of the pans into the troughs *b*, or passing off by the flues *h*. Each pan is fired by 3 fires, and boiled as for fine salt, while the spindle carrying the arms and scrapers is made to rotate. The incrustation of the pans is thus for the most part avoided, while very fine salt is produced, and is swept by centrifugal motion into the troughs, whence it is continuously ladled with a scoop, drained on "hurdles" *c*, and sent to the stove or the butter-salt bins, as the case may require. The steam-pipes discharge beneath the two fishery-salt pans, occupying the central position in the figures, while the gases from the fires under the pans, and perhaps from the fire of the engine, are made to pass to the flues beneath the outer pans. Both the pans which are heated by the steam stand on short brick or iron columns without flues; the pans taking the waste gases are set upon winding flues such as already described as being in frequent use in France.

At the works of the British Salt Co., at Anderton, a 3–4-H.P. engine stirs three pans, and it is stated that, with a consumption of 40 tons of coal, a pair of these pans, with their concomitant fishery-salt pans, will turn out 60 tons of fine salt and 24 tons of fishery-salt per week. The fine salt produced in these machine-pans is very fine and fairly white, but usually contains just a trace of iron, which communicates to it the faintest possible shade of yellow.

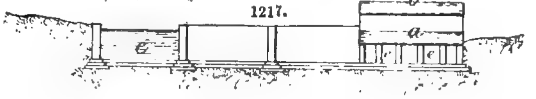
Sometimes an ordinary boiling-pan is mounted with a fishery-salt pan behind it, so that the flues from the former passing beneath the latter, this pan also becomes heated by the waste gases. The Cheshire Amalgamated Salt Co., one of the largest and most important of the district, have in their works at Winsford some rather interesting and peculiar composite pans, known as "clay" or "tank" pans, also working on this principle. Fig. 1215 represents a ground plan of this arrangement, and Figs. 1216, 1217, 1218, are transverse sections on the lines D E, F G, B C, respectively. The boiling-pan *a* is placed with its upper edge on a level with the ground or barely above it. It is of the usual depth of 1 ft. 9 in., and of the form shown. The fishery-salt pan *b* utilizes the waste heat of the furnace-gases, after they leave the flues beneath *a*. There are 3 fire-places *f*, and 3 flues *e*, beneath *a*, together with 2 dead flues. Alongside of and parallel with the pans *a b*, is a pit or trench *c*, about 4 ft. deep, 10–12 ft. wide, and 38–40 ft. long. It is puddled with clay and lined with bricks throughout the sides and bottom. The upper edges of this trench are about 4–5 in. below the level of the upper edge of the pan *a*. A parting wall of brickwork also divides this trench *c* longitudinally into 2 compartments of equal width. This wall, however, only goes to within about 10 ft. of the end of the trench furthest from the fires, and to within 2 ft. of that end which is in a line with them. The side of the pan *a* turned towards the trench is cut out at the end furthest from the fires, and a shallow channel of sheet-iron, just as deep as the pan, connects it with the double trench, while the space *k* contained between *a* and the trench is filled up with a bed of masonry, the surface of which slopes gently from the upper edge of *a* towards *c*, so that the waste brine from any salt drawn on to it may drain into *c*. *k* is connected with *d*, as shown in Figs. 1215 and 1217, by a short wall, and a pump is placed at *h*, while another sheet-iron channel, only 2 ft. wide, but of the same depth as *d*, leads between the pump and the pan *a*. There is a small pit *g*, made of masonry, at the end of this channel; and at the end of the parting wall, at *d*, is a flat space just large enough for a man to stand upon to look after the pump when requisite. With this arrangement, if brine be poured in by the brine-pipe *i*, *c* will be filled, and if the influx of the brine be continued, *a* and *b* may be filled till *c* is nearly overflowing, and *a* becomes full to within 4–5 in. of its upper edge. If then the pump *h* be worked so as to lift the brine from *c* and cause it to fall into *g*, it will flow back into *a*, and, circulating through *a*, will pass again into *c*; thus a steady circulation of the brine may be maintained in the directions shown by the arrows on the ground plan, so long as the pump is kept going. If then the fires *f*, Fig. 1218, be lit, the brine will be heated in *a*, and, circulating in the manner described, expose a large evaporating surface. The heat is so managed in these pans as to produce butter-salt in *a* and common salt in *c*; while at *g*, where the pump produces constant agitation, very fine salt is formed. Around the clay pan, the butter-salt pan, and the fishery-salt pan, are the usual paths for the circulation of the workmen, and the places for the so-called " hurdles " *m* upon which the salt is thrown to drain. The stoke-hole is below the level of the ground. The fishery-salt pan *b* may be mounted on columns of brickwork or cast-iron without separate flues, and a chimney at the end of this pan carries off the furnace-gases. These pans seem to produce very fine qualities of salt, particularly the common salt from the pit *c*. The yield is about the same (as regards weight of salt to weight of coal consumed) as with the ordinary pans, but the repairs are somewhat less, and certainly the qualities of salt produced are very fine. The chief drawback to them is a rather greater tendency of the pan *a* to become coated with scale, than in the case of the ordinary butter-salt pans.

1215.

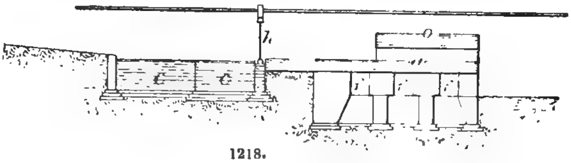




1216.



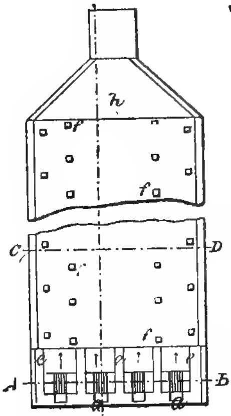
1217.

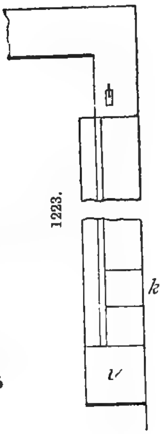


1218.

The last innovation in the salt manufacture here to be described is that of Otto Pohl, salt manufacturer and merchant, of Liverpool. This invention has, perhaps, not met with all the attention it deserves on the part of the salt manufacturers. The arrangement consists of two superimposed pans, at one end of which the fires are placed ; the heated gases, passing between them to the chimney at the other end, heat the upper pan from below in the ordinary way, while they sweep the surface of the brine in the lower pan, which thus constitutes the bed of this portion of the flue. Figs. 1219, 1220, 1221, 1222, 1223, and 1224 show this arrangement in ground plan, longitudinal and transverse sections, and in side and end elevations. Milner, of Marston, near Northwich, has a pan mounted on this same principle, which Pohl states to be an adaptation of the principle of the salting-down pans of the alkali-makers. His arrangement, however, differs from that of Pohl in that the upper pan is dispensed with, being replaced by an arch of brickwork. According to Pohl's system of construction, the lower pan is 5 ft. deep. It may be made of boiler-plate or of cast-iron, or, for that matter, the bottom and lower parts of its sides might very well be made of elm or pitch-pine, with cast-iron ends and framing. Pohl tried brickwork for the construction of this lower pan, but abandoned it on account of leakage. In the pan figured, however, he has formed the bottom of tiles embedded in clay. Pillars of cast-iron rising from the bottom *i* of this lower pan support the upper pan, which is of the ordinary make, and demands no special description. The interval between the two need not, according to Pohl, be more than 3 in. In practice, however, 5–6 in. is not too much from the bottom of the upper pan to the surface of the brine in the lower one when completely filled. The length of these pans is about 60 ft.; breadth of the upper one, about 20 ft., and of the lower one, 22 ft., the space between the two being filled all around with brickwork. Milner has made the lower pan in his arrangement much wider than this, or rather it may be said a lip or opening running all along each side of the lower pan permits of the salt as it collects being drawn to the sides by rakes, and lifted out by perforated scoops as it accumulates. According to Pohl's arrangement, this might easily be managed by continuing the sides of his upper pan downwards for say 8–9 in., the pan being placed at such a height above the lower pan that these sides may dip 2–3 in. below the surface of the brine in the lower pan, and thus constitute a flue *f* 4–5 in. deep, through which the furnace gases might pass. The lower pan might then be made say 3 ft. wider than the upper one, so as to leave a trough on each side about 18 in. wide, through which the salt might be drawn. As it is, when the pan has to be drawn, which, of course, must be done as soon as it becomes full of salt, the fires have to be let out, the brine run off, and the salt drawn by the door or manhole, *k*, Fig. 1223.

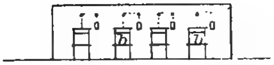
1219.



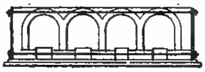


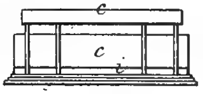
1223.

1224.

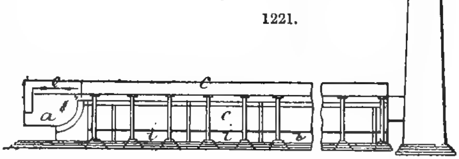


1222.





1221.



1220.

The furnaces in Otto Pohl's arrangement are four in number; they are made about 4 ft. wide internally, and 4½ ft. or even up to 6½ ft. between the top of the arch and the grate bars; a distance of 3 ft. or so is also left at the back between the end of the grate and the lower pan, the angle being filled up with a curve of masonry as shown at *e*, Fig. 1219. This form of construction is intended to allow space for more perfect combustion, before the heated gases enter between the pans, where they tend to become rapidly cooled, with proportionate liability to deposit soot. Fig. 1224 shows the front elevation and the arrangement of the sliding doors *b*. Pohl at first carried his upper pan right over the fires. He now stops short behind them, covering them in with arches of massive brickwork, so as to avoid as far as may be loss of heat by conduction in this quarter. He also proposed to make a sort of short circuitous flue, through which the products of combustion might be made to pass on their road to the space between the pans, by building three arches over the fires, constructed so as to reach alternately to the back and to the front of the fire-place, like the shelves of pyrites-dust kilns (see p. 84). These arches becoming strongly heated would aid in promoting the combustion of the smoke, while they served to catch the dust and ashes carried over from the fires. This plan, however, he appears to have abandoned. A further provision was made for getting rid of soot by keeping the lower pan always filled to the brim, making the end of it furthest removed from the fires a trifle lower than the fire end and sides, and keeping it full to the brim at that end. Much of the soot falling on the surface of the brine in light flocks, would float thereon, and be carried off over the end of the pan by the draught towards the chimney.

Between that end of the pan and the entrance to the chimney, is a soot-box or closet *h*, with a door for cleaning it out. Notwithstanding all these precautions, large quantities of soot are liable to become condensed, either upon the bottom of the upper pan, or between the two pans, and, falling on the surface of the brine, get carried down and mixed with the salt, rendering it black and totally unfit for food. This quality of salt, however, has been found specially suitable for the Hargreaves' salt-cake manufacture (see p. 287), so that the small quantities now produced find a ready enough sale, as the soot does not signify. The method shows an important economy of coal, and, according to Pohl, gives 3 tons of butter-salt with the same amount of fuel and labour as is requisite for producing 2 tons by the old methods. The use of gas from a Siemens' producer would obviate the soot completely, while it is probably preferable (according to Milner's plan) to do away altogether with the upper pan, employing merely a brick or tile covering as a reverberatory and radiating surface to throw the heat down into the lower pan, and so get rid of leakages, salt cats, and much cobbling and repairs involved in working by bottom heat. According to some experiments by Pohl, while the temperature of the upper pan remained suitable for making common salt, or ordinary fishery-salt, that of the surface of the brine in the lower pan was maintained at full boiling, and the produce, so far as grain was concerned, was very fine butter-salt, while no scale worth mentioning forms in the lower pan. He gives as a result of 16 days' boiling with brine containing 25·27 per cent. salt, for 57 tons of slack (from Little Houlton Colliery, Lancashire) burnt,—82 tons of fine butter-salt, and 49 of common salt; while on the old system, the 82 tons butter-salt would have taken 54 tons 13 cwt., and the 49 tons of common salt, 26½ tons, or a total of 81 tons 3 cwt., showing an economy of 24 tons 3 cwt. Instead of the gases escaping into the chimney at a temperature of 315° (600° F.), as during the manufacture of salt with the ordinary common salt pans, or at a temperature of 425°–538° (800°–1000° F.), as when making butter-salt, they never rose, even with the strongest firing, above 142° (288° F.).

Pohl states that in a subsequent trial, after lifting the top pan at the end nearest the fires to a height of 6 in., and lowering the other end to within 3 in. of the surface of the brine in the bottom pan, he obtained, as an average result of a series of boilings, 3 tons of salt for 1 ton of slack, the gases passing off at a still lower temperature; while in the top pan, 93°–98° (200°–208° F.) was the temperature attained in front, 82° (180° F.) in the middle, and 71° (160° F.) at the far end.

1225.

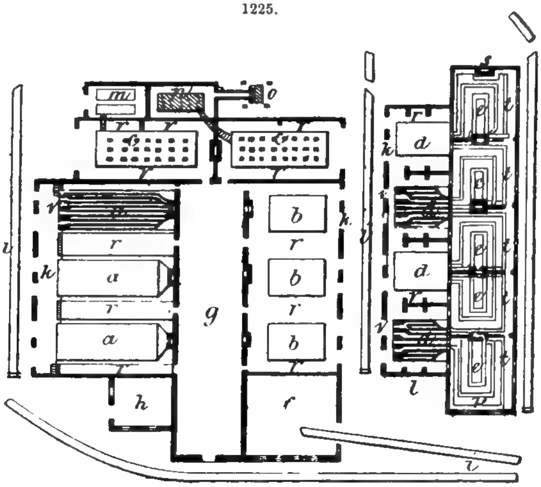


Fig. 1225 will serve to convey an idea of the usual arrangement of a salt-works, and will easily be understood from the foregoing descriptions. One of the fishery-salt pans *a* shows the disposition of the flues beneath, the outer flue on each side being called the "dead" flues. The spaces *r* throughout the building are pathways for the service of the pans and the "hurdles" on to which the salt is drawn. The fine salt-pans *d* have stoves *e* behind them, through which the flues circulate, and abut upon the chimneys *s*. Two of the fine-salt pans are shown with the dead flues on each side. At each end of the shed, and on each side of these fine-salt pans, are recesses in which the square and conical tubs used for moulding and draining the fine salt are kept ready to hand. The butter-salt pans *b* and fishery-salt pans *c* are heated respectively by the waste steam and waste heat of the fire gases from boiler and engine *n o*; *k* are the stoking pits of all the pans; *f* is the coal-store; *h*, the workshops for repairs; *g*, the salt-store; *i*, a railroad for the service of the works; *m* the offices.

The profits on salt manufacture in England are extremely small, owing to severe competition. In France, the saltmakers of each great region of production have constituted syndicates, by which the prices of salt and the scale of manufacture of each works are regulated, while they are protected from external competition by the peculiar conditions of the heavy excise duty, and the difficult formalities of the customs respecting imports of foreign salt. According to evidence given before the late Parliamentary commission, already referred to, the cost price of manufacturing common salt in the Winsford and Northwich district is about as follows:—Brine, 6*d.* a ton; labour, 10*d.*–1*s.*; coal (slack), 3*s.*; rent, interest on capital, &c., 1*s.*; total, 5*s.* 4*d.*–5*s.* 6*d.* a ton. These prices are subject to important variations. The cost of brine is always rated at so much per ton on the salt produced, and it varies for different works: at Northwich, for instance, 4–9*d.* per ton of salt is charged for brine; but 6*d.* may very well be adopted as a fair average price. The cost of coal likewise varies continually. The "burgey" used in making the boiled salts was, in the beginning of 1870, at 6*s.* 5*d.* a ton, rising to 9*s.* in 1872, and to 16*s.* and even 20*s.* in 1873. High prices continued till 1875, when they again began to recede, and, in 1878, ranged from 7*s.* to 8*s.*, falling in 1879 to 7*s.* 2*d.*–7*s.* 4*d.*, and in 1880 to 7*s.*–7*s.* 2*d.* The cost of the slack used in making common salt may be rated at about 1*s.*–1*s.* 6*d.* a ton below the prices of burgey. It is commonly admitted in Cheshire that an advance of 6*d.* a ton on slack means about 3*d.* a ton on common salt; and 6*d.* a ton on burgey, 4½*d.* a ton on boiled salts. The cost of carriage from the works to the canal on the banks of the Weaver also varies at the different works from nothing to 1*d.* and up to 4*d.* a ton.

It is thus difficult to fix any exact figure for the cost price of manufacture of salt in Cheshire, but the above may be taken as a near approximation in most cases. The carriage of the salt to Liverpool is performed in barges or "flats" on the Weaver; the selling price in the Liverpool market is 9*s.*, of which the works price is considered to be 5*s.* 6*d.*, and the official price of carriage 3*s.* 6*d.* To Runcorn, the carriage is 2*s.* 6*d.* The salt manufacturers may all be said to do their own lighterage, so that, as a matter of fact, any profits realized may be considered to be the 1*s.*–1*s.* 6*d.* gained on this score. The selling (i. e. the works) prices of salt in Liverpool (salt is rated there at present at the works prices), have been as follows:—The minimum price in 1871 was 6*s.* a ton; in 1872, prices varied from 7*s.*, 7*s.* 6*d.*, 10*s.* 6*d.*, to 17*s.*, and up to 20*s.*; in 1873, they were 14*s.*, 15*s.*, and down to 12*s.*; in 1874, they fell from 12*s.* to 8*s.*; in 1875, they kept nearly steady at about 9*s.*, falling however suddenly during one month of that year; in 1876, prices fluctuated from 8*s.* down to 5*s.*; in 1877, they even fell to 4*s.*, rising again to 7*s.*; in 1878, they were at 7*s.*, and fell to 5*s.* 6*d.*; in 1879, they again went as low as 4*s.* 6*d.*, running on into 1880 through 4*s.* 6*d.*, 4*s.* 9*d.*, to 6*s.* 6*d.*, and back to 6*s.* In the spring of the present year (1881), the works price was rated at Liverpool at 5*s.* 6*d.* for common salt. The salt manufacturers have repeatedly attempted to syndicate themselves after the manner of their Continental brethren, but as often their associations have been dissolved by disagreements springing up amongst them, at once entailing ruinous competition, and precluding all possible profits. The "Pool scheme," at one time in vogue in Liverpool, seemed to work satisfactorily for a short period. Under this plan, the works price was rated to the syndicate at 5*s.* 3*d.*, but the selling price was fixed and maintained at 8*s.* 3*d.*, 3*s.* being paid into a pool for the general *pro rata* profits of all. The plan, however, soon broke down through dissensions, and prices fell to ruinous rates. At the present moment, no saltmakers' association exists in England.

H. E. Falk furnishes the following list of salt exports from the Mersey:—

	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
The United States of America	182,939	153,206	222,612	176,885	212,532	215,100	223,346	216,258	256,920	261,687
British North America	94,382	67,634	59,869	56,024	54,807	58,103	65,918	71,624	78,171	109,836
West Indies and South America	9,130	6,704	5,616	6,343	4,442	5,815	6,522	5,860	9,404	14,064
Africa	22,685	19,438	21,784	26,747	25,507	23,132	24,580	24,513	20,610	35,475
East Indies	271,119	233,109	199,460	256,055	311,107	232,169	215,867	212,900	286,848	309,793
Australasia	9,192	9,792	17,208	12,309	24,918	13,908	20,564	15,600	13,517	24,474
Germany	38,495	34,310	35,716	28,394	32,474	43,618	28,804	23,479	22,844	37,859
Russia	40,591	50,762	70,496	61,802	49,200	73,893	49,991	43,232	42,452	41,177
Other Baltic and North Sea Ports	19,597	17,843	16,490	21,609	20,315	19,909	21,081	24,219	22,271	21,485
France and Mediterranean ..	1,898	1,130	1,706	2,243	889	1,055	1,680	1,053	809	2,381
Coastwise	91,720	71,608	54,614	51,533	72,268	66,555	47,530	44,604	33,045	39,087
Holland	18,339	19,384	19,653	27,400	23,652	22,102	20,107	19,204	18,922	18,910
Belgium	42,205	31,870	36,771	33,233	39,265	33,654	34,929	33,290	41,454	40,493
Export from Liverpool	842,292	716,790	761,995	760,577	871,376	809,013	76,019	735,836	847,267	956,721
Export from Runcorn and Weston Dock	213,435	166,583	148,956	177,958	161,111	173,614	182,638	233,668	239,583	244,785
Total from the Mersey ..	1,055,727	883,373	910,951	938,535	1,032,487	982,627	943,557	969,504	1,086,850	1,201,496

The Director-General of the French Customs has kindly furnished the following table of quantities of salt produced in France during the last 7 years (in French tons of 2204 lb.):—

Years.	Sea Salt.		Saltworks of the N.-E. and S.-W. White Salt (1).	Total.
	Mediterranean.	Atlantic Coast.		
1874	255,303	253,800	229,459	738,562
1875	195,965	177,666	230,063	603,694
1876	168,384	157,059	252,050	577,493
1877	293,047	(2) 44,526	252,833	590,406
1878	283,727	(2) 29,020	258,237	570,984
1879	240,577	(2) 3,039	213,471	457,087
1880	286,685	78,358	239,404	604,447

(1) In this column, the make of the S.-W. saltworks may be estimated at 10,000–11,000 tons.

(2) The rains and floods rendered the production of the Atlantic coast almost nil during the years 1877, 1878, and 1879.

The author desires to express his indebtedness to Messrs. Blades, Falk, Ward, Wigner, Botta of Nancy, and Archibald of Florence, for many valuable details and figures. F. M. L.

SILK (Fr., *Soie*; Ger., *Seide*).

The term "silk" is employed to denote the fibrous material produced by a number of insects for the purpose of forming a "cocoon" or nest in which a certain period of their existence is passed. The material composing this fibre is called "serisine," and is a product of the insect itself, exhibiting slight variations according to the species, and according to the food. It is the strongest, the most lustrous, and the most expensive of all organic fibres.

Raising.—Hence, the cultivation of the worms which produce the fibre has attracted attention from time immemorial, and silk-raising is one of the most profitable industries that can be undertaken in suitable climates. The first step in sericiculture is to secure a supply of food for the worms. For this purpose, the leaves of the mulberry seem to be unequalled. There are many species and varieties from which to choose, and preference should always be given when possible to that whose leaves afford the best sustenance to the worms, as indicated by their own predilections. Spotted and mildewed leaves must be avoided, and great care must be taken that the leaves are supplied fresh, dry, and clean, and particularly not heated or fermented. The points to be borne in mind in arranging a *magnanerie* or silkworm nursery are as follows:—A free circulation of air, without draughts, the windows never being opened on the windward side, except in the tropics; plenty of light, but no actual sunshine in hot climates; avoidance of all scents and odours, whether pleasant or otherwise, and of all noise; the temperature and moisture of the atmosphere of the chamber must be carefully watched and regulated. Electrical disturbances induce a kind of dysentery or cholera in the worms, which disease can only be stamped out by killing all the afflicted worms and all those which have been in contact with their excreta, as well as removing all excreta-stained leaves, nets, &c. Another disease, which has become a serious epidemic, is immediately caused by a fungus, called *Panhistophyton*; its germs may be discovered as microscopic cylindrical corpuscules in the blood of infected worms. Hence the necessity for thorough microscopic examination of every pair of moths before their eggs may be considered sound. The examination may be made after the moths are dead and dried, by grinding them into a paste with a little water.

This system of microscopic selection should be rigidly adhered to. Before removing the silk from the cocoon, it is necessary to kill the chrysalis inhabiting it. This may be done by placing it in an oven at a temperature not exceeding 93° (200° F.); but a much superior plan is to subject it for a few minutes to dry steam, which has a cleansing action upon the silk, and does not at the same time make it brittle.

The silk of which the cocoon is formed is one solid thread of great length (even 500 yd.), which has been wound from the outside towards the centre, and diminishes in size as it proceeds, till reduced to ⅓ or ¼. It is detached and prepared for use by a process termed "reeling." There is always a certain portion left which cannot be reeled; this may be carded and spun. With this object, large quantities of "husks" or "knubs," as the waste cocoons are called, are exported to Europe from the great silk-growing countries of the East, and the product thus obtained is known as silk "waste." Reeling is an operation requiring considerable practice and skill for its proper performance. There are several handy machines in the market for the purpose, and choice should be made of one of slow motion for beginners.

It may be useful to state that Chinese silk, by far the most important commercially, is put up in bales of the following weights:—Fine raw silk, 80 *catties* (of 1⅓ lb.); raw wild silk, 1 *picul* (of 133⅓ lb.); hydraulic-pressed waste silk, 2 *piculs*; cocoons, 1½ *piculs*.

Production and Commerce.—The silk production of Europe may be approximately estimated at 9 million lb. yearly, while Asia affords an additional 11 million lb. for export to European markets. The chief contributors to this enormous total of 20 million lb. are as follows:—China, 8 million lb.; Italy, 6¼; France, 1¼; Japan, 1¼; Turkey, 1¼; India, 1; Persia, Georgia, &c., 1. Some remarks upon the silk industry of each of these countries will now be given in the order just stated.

China.—The total silk production of China is officially stated at about 23,232,000 lb. annually, of which, some 16,588,000 lb. is afforded by cultivated mulberry worms (*Bombyx mori*), 1,364,000 lb. by wild worms on mulberry and other trees (*B. mori*, *B. atlas*, &c.), 660,000 lb. is raised from the ailanthus worm (*B. cynthia*), and 4,620,000 lb. from oak-feeding worms (*B. Pernyi* and *B. mylitta*). It will be convenient to consider each province under the head of its treaty port.

1. Newchwang.—The raw silk grown for export in Sheng-king is entirely from *B. Pernyi* [*Fantoni*], fed on the leaves of *Quercus mongolica* [*robur*]. The silk regions of this province are two:—A tract of 80 × 150 miles lying E. of the Liao River, the home of *B. Pernyi*; and a large portion of Liaohsi, scantily producing *B. cynthia*. In the former, one valley affords 12,000 cub. ft. of cocoons, and the yield throughout the district could be increased tenfold by planting the hill-sides with oak-shrubs. As reeled by the natives, the silk contains 20 per cent. of gum, and the excess of soda used to remove it decreases the value of the fibre for export; but properly reeled, it boils white, takes any dye, and can be used for tram. Native reeling gives 1 lb. silk from 10 lb.

cocoons. In water-reeling, the cocoons are placed in an iron pot with crude, strong, native soda, and covered with water; when the gluten has dissolved, the threads of 8-10 cocoons are caught up together and reeled off. By the dry-reeling system, the cocoons are first boiled in strong alkaline solution, and then reeled from a table at *uso doppio.* The chrysalids are killed by steaming 2500 at a time in small baskets. The silk of spring cocoons is much less in quantity than from autumn, but much whiter and finer in quality. A black silk is produced near Kaichow by *B. Pernyi*, where it devours the petiole, ribs, and veins of the oak-leaves. The cocoons of the district give an average of 500 *mètres* of silk, a weight of 0·432 *grm.*, and a "title" of 7440 *deniers.* Scarcely any disease is known among the hardy worms of Manchuria, and they have been recommended for restoring the worn-out European race. They are fed only on *Q. mongolica* when obtainable, but failing this, on *Q. custaneæfolia* and *Q. dentata.* These trees are all pruned back to 5-6 ft. high. The exports of raw silk from Newchwang in 1879 were 60 *piculs* (of $133\frac{1}{3}$ lb.) of wild.

2. Tientsin.—Silk-culture in Chihli, Shansi, and Honan is of small importance. Chihli annually produces about 300 *piculs* of cultivated and 700 of wild silk; of the former, about $\frac{4}{10}$ is yellow and $\frac{6}{10}$ white. Shansi only yields about 700 *piculs* of raw silk yearly, 500 being wild. Honan yearly affords about 6000 *piculs* of white and 1000 of yellow cultivated silk, and 3000 of wild.

3. Chefoo.—The annual production by worms fed on mulberry-leaves is about 80 *piculs* of white and 1024 of yellow raw silk; that of worms fed on ailanthus, about 6 *piculs*; that of worms (2 kinds) fed on oak-leaves, 7125 *piculs* of wild raw; that of wild mulberry-feeding worms, 15 *piculs.* The exports from Chefoo in 1879 were 1000 *piculs* of yellow, 750 of waste, and 500 of raw silk.

4. Ichang.—The average yearly production of raw silk from mulberry-feeding worms is 2000 *piculs* in Hupeh, 10,000 in Szechuen, and 400-500 in Kweichow; by wild worms frequenting mulberry-trees, about 1000 *piculs* in Kweichow. The exports from Ichang in 1879 were 750 *piculs* of yellow Szechuen and 18 of white ditto.

5. Hankow.—The total raw silk grown in Hupeh is estimated at 6000 *piculs* annually, and in Szechuen at 15,000, of which only about $\frac{1}{10}$ is white. The exports from Hankow in 1879 were 7000 *piculs* of raw Szechuen, 425 of white, 425 of cocoons, and 150 of refuse.

6. Kiukiang.—A very small quantity of raw silk is produced in the northern part of the province of Kiangsi, but the quality is inferior, and none is exported. The worms are fed on mulberry-leaves.

7. Wuhu.—Of the raw silk produced in the province of Anhwei, the colour is somewhat inferior and the quality coarse. The average yearly quantity is 600-800 *piculs* from worms fed on mulberry-leaves. The export in 1879 was 400 *piculs* of raw silk.

8. Chinkiang.—Domestic worms are reared on mulberry-plants. These latter are of two kinds, wild and cultivated. The wild kind is sturdy in growth, but has thin small leaves, so the general practice is to graft the cultivated variety upon it. The plantations are made on high plains. The trees are pruned back to a height of little over 5 ft. They are liable to the attacks of two insects, one penetrating below the bark, the other not. The former is detected by a greasy exudation from the bark; the place is cut open, and the larvæ are destroyed, or, if they have already become insects, they are killed by the insertion of a wire or the introduction of wood-oil into their holes. The second kind attacks the leaves; it is destroyed by sprinkling the trees with a strong solution of the juice of tobacco-stalks. The wild mulberry is neither grafted nor pruned, the largest trees reaching a height of 50-60 ft. The silk of worms fed on the wild mulberry is very coarse and inferior. Worms that have once tasted cultivated leaves will not eat wild ones. There are ten precepts observed in breeding the worms:—(1) The eggs when on paper must be kept cool; (2) after hatching, they require warmth; (3) during moulting, they must be kept hungry; (4) between their sleeps, they must be well fed; (5) they should be neither crowded nor too far apart; (6) during sleep, they should be kept dark and warm; (7) when their skins are cast, they need coolness and plenty of light; (8) for a short time after moulting, they should be sparely fed; (9) when fully grown, must never be without food; (10) the eggs should be laid close together but not heaped up. It may be added that smoke, draughts, and smells of all kinds are injurious to the worms, and great care needs to be taken that the leaves shall always be fresh, dry, and quite clean.

The worms, as fast as they are ready for weaving their cocoons, are transferred to hills made of straw. Any that are black or putrid are discarded. When the spinning is finished, the cocoons are removed, freed from the loose silk around them, and spread out on large trays in a cool spot. Flossy, maggot-bitten, sick, misshapen, urine-stained, and double cocoons are carefully picked out, as being unfit for reeling. The hardest, cleanest, and whitest cocoons are reserved for breeding purposes.

Wild worms are fed on *Quercus sinensis*, *Q. serrata*, and *Q. mongolica.* The last is 5-6 ft. high, and is grown around the villages for its leaves. The silk produced by it is hard. Two crops of cocoons are gathered annually from wild worms. They are smaller than the domestic ones, and of greyish-black colour.

9. **Shanghai.**—In the province of Chiangsu, the average quantity of raw silk produced for export from worms fed with mulberry-leaves is about 500,000 lb.; and in the province of Chêhchiang, about 6,500,000 lb. The product from wild worms frequenting mulberry-trees is about 4000 lb. The exports from Shanghai in 1879 were 60,350 *piculs* of raw, thrown, and yellow, 620 of wild raw, 6134 of refuse, and 1888 of cocoons; the exports are mainly destined for France, India, and Great Britain.

10. Ningpo.—The production of raw silk by worms fed with mulberry-leaves is about 6,500,000 lb.; and by wild worms found on mulberry-trees, 4000 lb., only in the district of Sharanglin. The export in 1879 was 350 *piculs* of raw silk.

11. Canton.—The average production of raw silk in this district may be stated as follows:—Exported to Europe, 12,000–14,000 bales (of 213 lb.); to Bombay, 3000–4000 *piculs*; to America, 10,000 boxes (of 150 lb.); and produced for native use, 20,000 *piculs*. This is exclusively afforded by worms fed upon mulberry-leaves. There is also a kind of raw silk spun by a worm frequenting the leaves of the camphor and kindred trees, not only on the Lofou Hills, but generally throughout the province of Kwangtung, though nowhere very abundantly. It is not cultivated, and very little silk is obtained from it, its chief use being for making "gut" (see p. 610), for which purpose, it is considered superior to the mulberry worm. The exports from Canton in 1879 were 16,200 *piculs* of fine raw silk, 130 of thrown, 7500 of refuse, 3500 of wild raw, and 2000 of cocoons.

12. Kiungchow.—The annual production is about 280 *piculs* of raw silk from worms fed on mulberry-leaves. There is also an average yearly production of 120 *piculs* of gut from a large caterpillar found on a tree growing in the centre of the island of Hainan, and supposed to be *Liquidambar formosana*. The export of raw silk in 1879 was 230 *piculs*.

13. Pakhoi.—The "gut"-yielding worm largely frequents the *Liquidambar* trees in this neighbourhood.

Our imports from China of raw silk fell from 4,984,800 lb. in 1876, to 3,165,935 lb. in 1880; while knubs, husks, and waste rose from 10,936 cwt. in 1877, to 31,402 cwt. in 1880. The approximate London market values of Chinese raw silks are:—16–19*s.* a lb. for Tsatlee No. 3, 11–16*s.* for Nos. 4, 5, &c., 9–18*s.* for Taysaam, and 10-16*s.* for Canton.

Italy.—Preference is given to the white mulberry (*Morus alba*) both in Italy and France for feeding silkworms. Great care is generally taken in carrying out Pasteur's method of microscopic selection of the moths in all large establishments. As to the yield of the different breeds, 1 oz. Japanese grain gives 35–45 lb. green cocoons; 1 oz. Japanese reproduced in Italy, 85–95 lb. green; 1 oz. Italian green, 130 lb. yellow; 1 oz. French striped (Var), 78 lb. nankin; 1 oz. Roussillon, maximum 175–190 lb. roseate-yellow. In 1879, about 80,000 cards of grain were imported from Japan, about 10 per cent. remaining unsold. In many districts, the cultivation of Japanese grain is almost nil, attention being exclusively paid to Italian grain yielding yellow cocoons giving a satisfactory product. In Lombardy, in 1879, a large proportion of the grain cultivated consisted of reproductions of green and crossed white and green Japanese breeds, while experiments on an augmented scale were made in cultivating the native yellow grain. In Piedmont, a certain quantity of grain imported from France and producing yellow cocoons was cultivated in addition to the Japanese varieties. In Venetia, the larger portion of the yield was composed of imported Japanese grain and Italian reproductions, the native grain forming but a small item. In Emilia, the yield was ¾ native and ¼ Japanese, either imported or reproduced in Italy. In Tuscany and the Marche, the bulk of the yield was from native grain giving yellow cocoons. The total yield of cocoons in Italy in 1879 was as follows:—

Region.	Yield.	Value.
	Kilo.	Lire.
Piedmont	4,155,618	20,670,631
Liguria	55,000	297,000
Lombardy	6,325,299	31,733,150
Venetia	3,569,439	19,627,023
Emilia	1,470,688	8,186,660
Tuscany	610,562	3,819,036
Marche, Umbria, Comarca	1,172,168	6,995,717
Neapolitan Provinces	1,413,775	5,802,564
Sicily	167,500	703,500
Sardinia	..	..
Total	18,940,049	97,835,281

Of this total, about 5½ million *kilo.* of cocoons were yellow, and 13½ million green. The production of raw silk was computed at 499,938 *kilo.* yellow, and 960,052 green. The exports from Naples in 1879 were 8753 *kilo.* of cocoons, 698 of raw silk, and 26,476 of waste; the values of the silk exports were 6286*l.* to Great Britain, 19,612*l.* to France, 440*l.* to Germany, 515*l.* to Turkey and Egypt, and 518*l.* to other countries. Our imports of raw silk from Italy fell from 24,552 lb. in 1876, to 36 lb. in 1877, and recovered to 36,643 lb. in 1880; of waste, knubs, and husks, from 155 cwt. in 1876, to 0 in 1878, and 84 cwt. in 1880. The approximate London market values of Italian silks are 24–26*s.* a lb. for Novi raw white, 22–28*s.* for Milan thrown, and 25–30*s.* for Piedmont thrown.

France.—The number of silk growers in France in 1874 was 198,043, 64,957 of these being on a large scale. Yet while France exported only 4,737,000 *kilo.* of raw and waste silk in 1879, she imported in the same year 10,889,000 *kilo.* The production is almost exclusively from cultivated worms fed on mulberry-leaves, but attention is being gradually given to the introduced ailanthus worm. There has hitherto been great difficulty in rearing the silk-worms *Attacus Yama-maï* and *A. Pernyi,* and other species feeding on oak-leaves, in Europe, on account of the early date at which the leaves are required. Much importance is therefore attached to the introduction of *Quercus Mirbeckii* from Algeria into S. France, as this species (or variety) develops its leaves in March, being fully a month in advance of all French oaks. Calais, in 1879, exported 1832 *kilo.* of raw and thrown, and 1769 of waste silk. Our imports from France of recent years have seen the following fluctuations:—Raw rose from 242,706 lb. in 1876, to 566,522 in 1877, and fell to 81,361 in 1880; waste, knubs, and husks fell from 9323 cwt. in 1876, to 6514 in 1877, and recovered to 14,169 in 1880; thrown fell from 144,660 lb. in 1876, to 32,033 in 1878, and reached 192,932 in 1880.

Japan.—The silk of Japan is produced almost entirely by cultivated worms fed on mulberry-leaves, several species of mulberry being grown for the purpose; but a certain and increasing quantity is afforded by *yama-maï* worms feeding wild on oak-trees, a hardier and more prolific race. Silk-growing is pretty universal in Japan, and has been greatly stimulated of late years, but there is room for much improvement in the reeling and other operations. Microscopic selection and machine-reeling are gaining ground. Our imports of Japanese raw silk fell from 448,541 lb. in 1877, to 240,326 in 1880; and of knubs, husks, and waste, rose from 470 cwt. in 1877, to 2577 in 1880. The approximate London market value of Japanese raw silk is 14–19*s.* a lb. for ordinary, and 16–21*s.* for fine to superior.

Turkey.—In Asiatic Turkey mulberry-trees grow almost everywhere, but are mainly utilized for silk and cocoons in the district of Broussa, the neighbourhood of Diarbekir, N. Syria, and the Lebanon. A species of wild silk called *gez* and *jel,* grows extensively in Kurdistan, between Zacho and Rowandooz, but although much prized and worked by the Kurdish women, it has not yet found its way into Western commerce. The export of the raw material and of cocoons from Broussa averages in value about 350,000*l.* a year. The cultivation round Diarbekir is less developed, but there also the soil and climate are excellently adapted to its pursuit on a large scale. In Syria, it rivals tobacco as a local staple; and in the lower and middle ranges of the Lebanon, employs a large number of hands. In all these centres of silk culture, the best filament is produced from Japanese eggs, but fraudulent substitutions for these have greatly damaged the quality of Turkish silk, and correspondingly affected the industry both at Broussa and in Syria. The silkworm disease has been very bad for the last three years, and has caused the production of high-quality silk to fall off very much, the silk produced from the seed brought from Japan and other countries being far inferior to the produce of native silkworms. These latter are described as yielding cocoons quite white in colour, and more than double the size of the yellow cocoons made by the Japanese worms. An opinion is prevalent that the disease will pass away in time, when it will be possible to return to the production of silk from native worms only. The exports in 1879 from Musyna were 15 tons cocoons, value 1650*l.*, to Turkish ports, and 1 ton, 120*l.*, to England; from Alexandretta, 10 tons cocoons, 6000*l.*, to France, 1 ton, 600*l.*, to Austria, 2 tons, 1200*l.*, to Turkish ports; from Dedeagatch, 800 bales cocoons, 20,000*l.*, and 150 bales silk waste, 800*l.*; from Trebizonde (Persian produce), 429 bales (of 1½ cwt.) of silk, 42,900*l.*, to Turkish ports, 55 bales (of 1¾ cwt.) of waste silk, 825*l.*, to Turkish ports, and 41 bales, 645*l.*, to France. Our imports from Turkey in Asia of raw silk fell from 5610 lb. in 1877, to 0 in 1879, and recovered to 520 lb. in 1880; of waste, knubs, and husks, 153 cwt. in 1876, 58 in 1877, 2027 in 1878, 688 in 1879, and 69 in 1880. The approximate London market value of Broussa silk is 24–29*s.* a lb.

Our imports of raw silk from Turkey in Europe were 4210 lb. in 1877, 784 in 1878, and 5821 in 1880; of waste, knubs, and husks, 362 cwt. in 1877, 94 in 1878, and 356 in 1880. Thessaly, in 1880, exported 20,000*l.* worth of silk and cocoons.

India.—Perhaps no country in the world is so rich in indigenous silk-producing insects as India. This is sufficiently indicated by the following list, arranged by F. Moore, curator of the India Museum:—

1. Mulberry-Feeding. *a.* Domesticated.—*Bombyx mori,* the common silkworm, domesticated in

China, Japan, Bokhara, Afghanistan, Cashmere, Persia, S. Russia, Turkey, Egypt, Algeria, Italy, France, and Spain, producing but one crop annually, spinning the largest cocoon and the best silk, of a golden-yellow or white colour. *B. textor*, the *boro poolloo* of Bengal, domesticated in S. China and Bengal; annual only; a white (sometimes yellow) cocoon, of a different texture and more flossy than *B. mori*. *B. sinensis*, the *sina*, *cheena*, or small Chinese monthly worm of Bengal, partially domesticated in Bengal, where it was introduced from China; several broods in the year, cocoon, white and yellow. *B. crœsi*, the *nistry* or *madrassee* of Bengal, introduced from China; domesticated in Bengal; 7–8 broods of golden-yellow cocoons in the year, of larger size than *B. sinensis*. *B. fortunatus*, the *dasee* of Bengal; several broods annually; the smallest cocoon, of a golden-yellow colour. *B. arracanensis*, the Burmese silkworm, domesticated in Arracan, said to have been introduced from China, through Burma; several broods annually; cocoons larger than the Bengal monthly species.

b. Wild.—*Theophila Huttoni*, the wild silkworm of the N.-W. Himálayas; worms found abundantly feeding on the indigenous mulberry in the mountain forests. *T. sherwilli*, the wild silkworm of the S.-E. Himálayas. *T. bengalensis*, the wild silkworm of Lower Bengal; in the neighbourhood of Calcutta feeding on *Artocarpus lacoocha*; also at Ranchee in Chota Nagpore. *T. religiosa*, the *joree* of Assam and *deo-mooga* of Cachar; feeds on the *bur* tree (*Ficus indica*) and the *pipul* (*F. religiosa*). *T. mandarina*, the wild silkworm of Chekiang, N. China; stated to feed on wild mulberry-trees, spinning a white cocoon. *Ocinara lactea*, at Mussooree, N.-W. Himálaya; feeds on *Ficus venosa*; small yellow cocoon; several broods during the summer. *O. Moorei*, at Mussooree, N.-W. Himálaya; also feeds on *Ficus venosa*, as well as on the wild fig; a small white cocoon; multivoltine. *O. diaphana*, on the Khasia hills. *Trilocha varians*, in N. and S. India.

2. Atlas and Eria Group.—*Attacus atlas*, in China, Burma, India, Ceylon, Java; almost omnivorous, feeding in different districts upon the shrubs and trees peculiar to it, as *Bradleia ovata*, *Falconeria insignis*, and several other trees at Mussooree; the yellow flowering barberry at Almorah; and various other trees at Cachar; cocoon well stored with a fine silk. *A. silhetica*, in Silhet. *A. Edwardsia*, in Sikkim, Cherra, and Khasia hills. *A. cynthia*, in China; domesticated in the provinces of Shantung and Honan; feeds on *Ailanthus glandulosa*. *A. Ricini*, the *eria* of Assam, and *arindi* of Dinajpore; domesticated in the N. parts of Bengal (Bogra, Rungpore, and Dinajpore), in Assam and Cachar; feeds on the castor-oil plant (*Ricinus communis*); seven or more crops annually; cocoons somewhat loose and flossy, orange-red, sometimes white. The so-called "Ailanthus silkworm" of Europe—the result of a fertile hybrid between the Chinese and the Bengal species—was produced some years ago in France, whence it was introduced into various parts of the world. *A. Canningi*, in the N.-W. Himálayas; common in a wild state, feeding on the leaves of *Coriaria nipalensis* and *Xanthophyllum hostile*; cocoons hard and compactly woven, rusty-orange or grey; annual. *A. lunula*, in Silhet. *A. obscurus*, in Cachar; not very common; stated to feed on a plant called *lood*. *A. Guerini*, in E. Bengal.

3. Actias Group.—*Actias Selene*, in Mussooree, Sikkim, Khasia hills, and Madras; feeds upon *Andromeda ovalifolia*, *Coriaria nipalensis*, wild cherry, and walnut, at Mussooree, and on *Odina Wodier* in Madras. *A. sinensis*, in N. China. *A. Leto* and *A. Mænas*, in Sikkim and Khasia hills. *A. ignescens*, in the Andaman Isles.

4. Tusser and Moonga Group.—*Antheræa mylitta* [*paphia*], the *tusser*, *tasar*, or *tussah* silkworm; well-known and valuable insects (of various undetermined species), widely distributed over India, from E. to W. and N. to S., on the coast, and in the Central Provinces; feed in a wild state upon the *ber* (*Zizyphus jujuba*), the *asun* (*Terminalia alata*), the *seemul* (*Bombax heptaphyllum*), &c. *A. Mezankooria*, the *mezankoorie* silkworm of the Assamese; stated to feed on the *addakoory* (? *Tetranthera quadrifolia*), which is abundant in Upper and Lower Assam; silk nearly white, its value being fifty per cent. above that of the *muga*. *A. nebulosa*, the *tusser* of the Sonthal jungles of Colong; also found in Singbhoom, Chota Nagpore. *A. Perrotteti*, in the districts of Pondicherry, feeding upon a species of *Zizyphus*, the *jambool* (*Syzygium jambolanum*), &c.; four broods in a year. *A. andamana*, allied species to the tusser, in the S. Andamans. *A. Frithi*, in Sikkim and the Himálayas; common, wild, inhabiting the hot subtropical valleys below 2000 ft.; cocoon is stated to be similar to tusser in form, but finer silk. *A. Helferi*, in Sikkim and the Himálayas; a common species in the hot valleys of Sikkim. *A. assama*, the *moonga* or *muga* of the Assamese; feeds upon the *champa* (*Michelia sp.*) the *soom* (? *Tetranthera lanceolata*), *kontoolva*, *digluttee* (*Tetranthera diglottica*), the *pattee shoonda* (*Laurus obtusifolia*), and the *sonhalloo* (*Tetranthera macrophylla*); extensively cultivated by the natives, and can be reared in houses, but is fed and thrives best in the open air and upon the trees; the silk forms an article of export from Assam, and leaves the country generally in the shape of thread. *A. Roylei*, the oak-feeding silkworm of the N.-W. Himálayas; common on the hill-oak (*Quercus incana*) of the N.-W. Himálayas (Simla, Masuri, Almora); cocoon large and very tough; silk pronounced as promising, and worth cultivating; can be reared easily in the house.

5. Miscellaneous Group.—*Salassa Lola*, Sikkim, Himálayas. *Rinaca Zuleika*, Sikkim. *Rhodia Newara*, Nepal (Kathmandoo); feeds upon a species of weeping willow; brilliant green cocoon,

pendant from the twigs. *Caligula thibeta*, Mussooree, N.-W. Himálayas, 7000 ft.; common, feeding on *Andromeda ovalifolia*, wild pear, and cultivated quince; light, open, net-like cocoon. *C. simla*, Simla, N.-W. Himálayas, 5000 ft.; feeds on the walnut, *Salix babylonica*, wild pear, &c.; open, net-like cocoon. *C. cachara*, Cachar. *Neoris Huttoni*, Mussooree, N.-W. Himálayas, 6500 ft.; worms appear in April, feeding upon a species of wild pear tree; thin silken cocoon. *N. shadulla*, Yarkand. *N. Stoliczkana*, Ladak. *Saturnia cidosa*, *S. Grotei*, *S. lindia*, and *S. anna*, hot valleys of the Sikkim Himálayas. *Loepa katinka*, Sikkim, 5000–7000 ft., Assam. *L. sikkima*, hot valleys of Sikkim. *L. sivalica*, Mussooree, 5000 ft.; long cocoon, pointed at each end, and of a dark greenish-grey colour. *L. miranda*, Sikkim, Himálayas. *Cricula trifenestrata*, the *haumpottonee* of the Assamese; very common in Assam; feeds on the *soom*; open net-like cocoon, of a beautiful yellow colour, and of a rich lustre, the silk being spun in the same manner as the *eria* cocoon; occurs also in Moulmein, where the worms are stated to feed upon the cashew-nut tree (*Anacardium orientale*). *C. drepanoides*, Sikkim. A few others which are well worth the attention of the Government of India for the purpose of acclimatization there are :—*Antheræa Pernyi*, the oak-feeding silkworm of Manchuria, N. China, described as having been long known to the Manchu Tartars, very large quantities of the silk being used among the Chinese; feeds on various species of oak (*Quercus mongolica*), &c., the cocoon differing from the tusser in form and texture; silk represented as strong, but with little lustre; two crops in the year—spring and autumn. *A. Confuci*, allied to *A. Pernyi*, inhabiting the hills in the neighbourhood of Shanghai, N. China. *A. Yama-mai*, the *yama-mai* silkworm of Japan; oak-feeding; cocoon of a pale yellowish-green colour; excellent silk of considerable commercial value in Japan; has been acclimatized in Europe, and, crossed with *Bombyx Attacus Pernyi*, is successfully reared in France, the eggs hatching at almost freezing-point. *Saturnia pyretorum*, S. China; feeds upon the *Liquidambar formosana* in Canton, Amoy. *Neoris shadulla*, Yarkand. *Theophila mandarina*, N. China.

The most important of the wild silks of India is the *tusser* (very variously spelt), or *Antheræa paphia* (with about a dozen synonyms). The worms feed indiscriminately on *Rhizophora calceolaris*; *Terminalia glabra* (the *assum*), *T. tomentosa* (the *saj*), and *T. catappa* (the country almond); *Tectona grandis* (teak); *Zizyphus jujuba* (the *ber*); *Shorea robusta* (the *sal*); *Bombax heptaphyllum* (the *semul*); *Careya sphærica*; *Pentaptera tomentosa* and *P. glabra*; *Ricinus communis* (castor-oil); *Cassia lanceolata*. The cocoons are curiously suspended from the branches of the trees. The insect is distributed over nearly the whole of India. In the Central Provinces, the silk is utilized in Rajpore, Bilaspore, Sumbulpore, the Upper Godavery, Chanda, Bhundora, Nagpore, Balaghab, Seonee, Chindwara, Betool, and Nursinghpore. Sumbulpore is said to yield yearly 7000 lb. of the silk; Rajpore, 12,000 lb.; Bilaspore, 1800 lb.; Chanda, 45,000 lb. Major G. Coussmaker, who has done so much to establish the domestic cultivation of this worm in the Deccan, finds that it thrives well on *Lagerstrœmia indica*, and still better on *Carissa carandus*; the former resumes thick foliage within a fortnight after having all its leaves eaten off. The filament of this kind of silk is of tape-like form, and not cylindrical as is commonly the case.

The *eria* worm is so called from the Assamese name of the castor-oil plant (*Ricinus communis*), on which it is almost exclusively fed. It is reared entirely indoors. The duration of its life varies with the season: in the summer, it is shorter, and the product is both better and more abundant. At this season, 20–24 days elapse from the date of its birth to the time when it begins its cocoon, 15 days later the moth is produced, in three days the eggs are laid, and in five more they are hatched, making the total duration of a breed 43 days. In winter, its life extends to nearly two months. Seven broods are reckoned upon annually. When the worms have ceased feeding, they are placed in baskets filled with dry leaves, amongst which they form their cocoons. In four days, the latter are complete. A selection having been made for the next breed, the remainder are exposed to the sun for 2–3 days, to destroy the vitality of the chrysalis. The cocoons are next generally put into water containing potash (wood-ashes), over a slow fire; when removed, the water is gently squeezed out. At other times, they are massed together for some days with *amrita* (? *Carica papaya*) or *madhu* fruit. The object is the same in either case, viz. to facilitate the drawing of the silk. It is coarse, and none of it ever finds its way into Bengal.

The *muga* moth is found wild in the jungles of Assam, but all the silk produced by it is from domesticated worms. They are reared on trees in the open air. There are generally five breeds in a year, viz. January–February, May–June, July–August, September–October, and November. The first and last yield the best crops, as regards both quantity and quality. Constant watching of the trees is necessary. The worms thrive best in dry weather, but a very hot sunny day at the moulting time proves fatal to many. Indeed, at this period, rain is considered very favourable; and even thunderstorms are not injurious, as they are to the mulberry worm. Continual heavy rains do mischief by sweeping the worms off the trees; but showers, however violent, cause no great damage, the worms generally taking shelter under the leaves with perfect safety. The total duration of a breed varies from 60 to 70 days. The chrysalis not being easily killed by exposure to the sun, a number of cocoons are placed upon bamboo stages, and covered with leaves, whilst a quantity of dry grass is ignited below them, and in a short time destroys them. The cocoons are then boiled for about an hour in water containing potash (the ashes of mustard and other plants). When taken out, they are laid between folds of cloth. The floss is removed by hand, and the cocoons are thrown into hot water. The instrument used for winding off the silk is the roughest imaginable. The Assamese consider it a good annual return if an acre of trees support 50,000 cocoons, yielding upwards of 24 lb. of silk. It must be very profitable, as 1000 cocoons are reckoned to afford 6–8½ oz. of silk thread, selling at 10–12*s.* a lb. The labour and expense of maintaining a plantation of the trees is very trifling. Lakhimpur, in 1871, exported 11¼ tons of *muga* silk thread, value 6090*l.*

The *mujankuri* (variously spelt) worm is really a variety of *muga*, feeding on the *mujankuri* or *adakuri* plant (*Tetranthera polyantha*). The silk is whiter and better, some of the thread produced in Sibsagar selling for 36*s.* a lb. It is rarely in the market.

The exports of Indian raw silk were 1,656,015 lb., value 766,462*l.*, in 1875; and 1,329,599 lb., 570,229*l.*, in 1879. Our imports of Indian raw silk fell from 150,232 lb. in 1876, to 105,006 lb. in 1880; and of knubs, husks, and waste, from 4396 cwt. in 1877, to 3404 cwt. in 1880. The approximate London market values of Indian raw silks are as follows:—Radnagore, 10–16*s.* a lb.; Surdah, 14–18*s.*; Gonatea, 11–17*s.*; Cossimbuzar, 11–17*s.*; Comercolli, 10–16*s.*; Hurripaul, 8–10*s.*; Jungypore, 11–15*s.*

Persia.—The exports of Persian silk, the produce of Ghilan, to Russia, in 1879, were 109,600*l.* worth of raw, 16,150*l.* husks, 1150*l.* cocoons. The exports of silk viâ Gez were 200 ballots, value 9230*l.*, from Asterabad, and 400, value 27,690*l.*, from Khorassan and Subzevar; while the refuse amounted to 400 ballots, 3840*l.* Bushire, in 1879, exported 2,30.000 *rupees'* worth of raw silk to India. The approximate London market value of Persian raw silk is 9–11*s.* a lb.

Other Countries.—The subject of sericiculture is attracting considerable attention in many other countries, though their production is at present insignificant compared with those just described. In America, the industry is taking a great start, especially in California, Texas, Georgia, Alabama, Connecticut, and Pennsylvania. The Australian colonies possess facilities second to no country in the world for the production of silk, and much may be expected from the efforts that are now being made in this direction. Cyprus formerly produced 70,000–80,000 lb. of silk, which is now reduced to 5000–8000 lb.; the mulberry flourishes everywhere, but the worms have long suffered from disease. Our imports of raw silk from Malta (not of local production) rose from 13,650 lb. in 1876, to 41,713 in 1878, but receded to 26,361 in 1880. The Greek provinces of Calamata and Messina produced 96,250 lb. cocoons, value 12,500*l.*, in 1880; Syra in that year exported 1074*l.* worth to France. Servia before the war of 1876 exported yearly 10,000*l.* worth of eggs and cocoons. Austro-Hungary in 1879 exported 9746 metrical *centners* (of 110¼ lb.) of silk. In the S. provinces of Russia, excellent silk is raised by the German colonists in Ekaterinoslav and Taurida; much is also produced in the Trans-Caucasian provinces. The inhabitants of Turkistan cultivate a considerable amount of silk, much of which finds its way into Russian commerce. Algiers in 1879 exported 15,938 *kilo.* of silk; and French Cochin China, 660 *piculs* (of 133⅓ lb.) in 1880. Uruguay promises to figure soon as a producer.

In England, the failure of numerous experiments has proved that sericiculture cannot be carried on profitably; but, according to no less an authority than B. F. Cobb, the rearing of grain or eggs for the Continental market would be a most remunerative and successful industry.

Imports and Exports.—Our imports of silk knubs or husks and waste in 1880 were:—31,402 cwt., 376,710*l.*, from China; 14,169 cwt., 239,452*l.*, from France; 3086 cwt., 36,738*l.*, from Bengal and Burma; 2577 cwt., 31,054*l.*, from Japan; 1667 cwt., 31,541*l.*, from the United States; 425 cwt., 6369*l.*, from Turkey; 1676 cwt., 28,592*l.*, from other countries; total, 55,002 cwt., 750,456*l.* Of raw silk in the same year:—3,165,935 lb., 2,663,850*l.*, from China; 240,326 lb., 204,202*l.*, from Japan; 81,361 lb., 79,416*l.*, from France; 72,051 lb., 50,336*l.*, from Bombay and Sind; 36,643 lb., 46,160*l.*, from Italy; 32,955 lb., 30,900*l.*, from Bengal and Burma; 26,361 lb., 38,090*l.*, from Malta; 18,317 lb., 17,702*l.*, from other countries; total, 3,673,949 lb., 3,130,656*l.* Our imports of raw silk in 1876 were 6,016,927 lb., value 5,770,341*l.*, since which they have yearly decreased. Our imports of knubs, husks, and waste, on the other hand, show a gradual increase from 29,633 cwt., 406,051*l.*, in 1876. Our re-exports of raw silk in 1880 were 947,165 lb., 741,597*l.*, about 70 per cent. being to France; of knubs, husks, and waste, in the same year, 9241 cwt., 102,809*l.*, over 80 per cent. being to France.

Bibliography.—B. F. Cobb, 'Report on Raw Silk' (Jour. Soc. Arts, Vol. xxi., No. 1080), 'Hints to Colonists on the Cultivation of Silk' (Vol. xxi., Nos. 1081, 1086, 1088, 1089, 1090, 1091, 1092, 1094), 'Rearing "grain" in this country' (Vol. xxv., No. 1262) [London: 1872–3, 1876–7]; A. Roland, 'Production of Silkworm grain' (Jour. Soc. Arts, Vol. xxi., No. 1066, London: 1872–3); G. Coussmaker, 'The Tussur Silkworm' (London: 1873); Mrs. Bladen Neill, 'Silk-growing: its Prospects and its Wants' (Jour. Soc. Arts, Vol. xxiv., No. 1223, London: 1875–6); E. T. Blakeley, 'The Silk Industry of N. Italy' (Jour. Soc. Arts, Vol. xxvii., No. 1364, London: 1878–9); 'Supplement to the Gazette of India,' Mar. 15 and Aug. 2, 1879 (Calcutta); A. Wailly, 'Silk-producing Bombyces' (Jour. Soc. Arts, Vol. xxvii., Nos. 1385, 1393, Vol. xxviii., Nos. 1421, 1424, Vol. xxix., Nos. 1475, 1476, London, 1879–81); T. Wardle, 'The Wild Silks of India, principally Tusser' (London; 1880), and 'Catalogue of specimens of wild silks of India' (Jour. Soc. Arts, Vol. xxviii., No. 1420, London: 1879–80); Imperial Maritime Customs' Report on Silk in China (Shanghai: 1881).

(See Silk Manufactures.)

SILK MANUFACTURES (Fr., *Soierie, Industrie sétifère*; Ger., *Seidengewerbe*).

According to the most reliable historic records, the Chinese were the first people to utilize the fine, lustrous, and beautiful fibre produced by the various kinds of silkworm (see Silk). The art of silk manufacturing appears to have arrived at considerable perfection 2750 years before the Christian era, as the empresses of China, at that early period, are stated to have busied themselves with their maids in the industry. To one of these empresses, Si-ling-chi, the consort of the Emperor Hoang-ti, is attributed the discovery and invention of a method of reeling the cocoons. The industry continued under the protection and often under the personal superintendence of her successors for many centuries subsequently. The beauty of the fabrics manufactured led in process of time to the growth of an export trade, first with neighbouring nations, and afterwards with those more distant. In this way, silk and silken fabrics penetrated into India, Persia, and the intervening territories, to the borders of Europe. Thence, by the aid of the maritime nations at that time flourishing in the Levant, they were distributed amongst all the ancient peoples who had risen to eminence in civilization at that early day. In the former case, the means by which this was effected were the caravans of merchants who travelled overland from one country to another.

Though the material at an early period thus became known in a manufactured and semi-manufactured form, its origin for centuries longer remained a secret. For a long time, it was conjectured to be a direct production of the vegetable kingdom, and is stated to be such by several ancient authors.

The substantial fabrics of silk that found their way to W. Asia from China were prized not only as valuable products of the loom, but also as affording an excellent source of the raw material, being in many cases unravelled, in order that the threads thus obtained might be rewoven to form the light and semi-transparent articles that excited the censure and ridicule of the moralists and satirists of ancient Greece and Rome.

The story of the introduction into Europe of the silkworm, and the methods of manufacturing silk as practised by the Chinese, by two Nestorian monks during the reign of the Emperor Justinian in 552 A.D., is too well known to need repetition. The emperor, with a keen eye to profit, kept the manufacture a monopoly in his own hands for a considerable time; but it was impossible to maintain such a state of things. Sericiculture and the manufacture rapidly spread over the most suitable territories of the Roman empire, and flourished especially in the Peloponessus. The new industry, though slow in its development, and for 600 years confined mostly to Greece, gradually gained upon that of China, and ultimately sufficed for the supply of the European demand. The Arabs and Saracen princes, who had also become acquainted with the art in both its branches from the Persians, had introduced it into the kingdons of Northern Africa, Sicily, Spain, and Portugal, over all of which they held sway. The Crusades about this period led to considerable political changes, amongst which was the establishment of the Norman power in Sicily. It is to the ambition of Roger, the first Norman king of that country, that the world owes the dispersion of the silk manufacture of Greece, and its introduction into Sicily and Italy. After this king returned from his second crusade in 1146, he invaded Greece, and carried off the treasures of Athens, Thebes, and Corinth, taking captive a large number of weavers and other operatives connected with the silk industry, whom he compelled to settle in Palermo and Calabria, and to teach his people their methods of manufacture. The Crusades also greatly assisted to make silk known in all the countries from which the motley armies of adventurers had been gathered. Those who returned would not fail to convey to willing feminine ears full details of the art of producing the glossy and much prized robes, of which many would only have heard vague reports. The manufacture had not been long established in Italy before it was carried into France.

Sericiculture and the manufacture of the product have always been a favourite pursuit and a cherished industry of the kings and aristocracies of Europe. The rulers of France for more than four centuries made it an object of peculiar care, and by the time of Louis XIV., it had become a flourishing industry, employing in its various branches probably over one million people. Amongst these were the Huguenots, whom the monarch just mentioned banished from their homes. In Lyons, at that date, were over 18,000 looms; and at Tours, over 11,000. These were reduced to about 5000, and even for these, weavers could not be found. The silk industry of France was thus almost annihilated. The result, however, was its establishment in Switzerland, Germany, and England; in the last country, over 100,000 of the refugees found an asylum for themselves and a profitable field for their labour.

Numerous attempts have been made in this country to acclimatize the silkworm, so as to render its cultivation profitable, but without success. Better results, however, attended the efforts to establish the manufacture. From a comparatively early period, it is probable that it was carried on with more or less success, though without becoming in any sense a distinct and recognized national industry. The immigration of the Continental refugees above mentioned, and their settlement in Spitalfields, Norwich, Dublin, and several other places, so increased and concentrated the industry in these localities, that it has been numbered amongst the most important of the textile manufactures of the country ever since.

For a long time, the machinery was rude, and incapable of producing more than "tram," the weft employed in making silken fabrics; whilst "organzine," or warp yarns, had to be imported ready "thrown" from Italy. This, as is well known, was obviated by the introduction of "throwing" machinery from Italy by John Lombe, of Derby, who surreptitiously acquired plans of the machines by engaging as a workman in an Italian mill. The risks he encountered and the obstacles he overcame before he made his establishment at Derby a success are too well known to need detailing here.

The success of the Derby mill soon led to the erection of others at Stockport, Congleton, Macclesfield, Leek, and numerous other places in and around Manchester. For a considerable time, the trade flourished in all these districts, and especially whilst import-duties were levied upon foreign productions, which had a tendency to preserve the home market to them exclusively. But the more profitable industries of cotton and woollen manufacturing, which have undergone such wonderful development, have quite put the silk manufacture into the shade. Owing to the greatly enhanced value of labour in this country, it has become almost impossible to compete against the cheap labour of the Continent without protection. The consequence is that since the repeal of the import duties upon silk manufactures, the trade has been gradually decaying when contrasted with the other textile industries of this country. Whether there is a future before it when its prosperity will revive, and its progress compare with them, is difficult to say.

Raw silk arrives in this country made up into "books," each containing a certain number of knots. That from Italy is twisted up into a thick knot, almost like a short length of rope, about 12 in. long. That from China and Japan is made up into much smaller knots than that of European origin, and a number of these are put together in the form of a brick.

Silk is emitted by the worm from two orifices termed "spinnarettes" in the form of two fine filaments, which the worm unites into one thread, of which it forms its cocoon. In winding the cocoons, five or six of these double threads are wound together, and slightly twisted to form a thread capable of being manufactured. Owing to the softened state of the natural gum of the silk caused by steeping the cocoons in warm water, as they are reeled and twisted, they readily unite into one thread. In this form, the silk is purchased by the "throwster" or spinner, provided he does not reel from the cocoon.

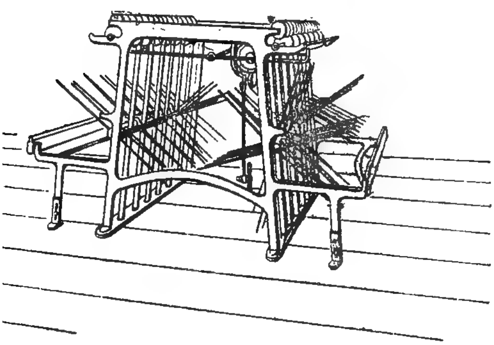
Raw silk in the processes of manufacture becomes either "organzine" or "tram," according to its treatment. The former is used for warp purposes, and generally consists of two "singles" twisted or "thrown" together. For fine warps, single alone is used. The weft yarns are composed of two or more singles, slightly twisted, in order to admit of the better distribution of the fibres over the warp threads, which they are usually intended to cover in the most perfect manner.

The processes through which it is necessary to put the raw material as imported into this country, in order to prepare it for organzine for weaving, are the following:—(1) Winding, (2) cleaning, (3) spinning, (4) doubling, (5) spinning, (6) reeling. The first operation of spinning, being of the "single," puts in about 15 turns to the inch of thread; the second, which combines two or more threads, imparts about 8 turns an inch. When tram is being prepared, the operations are nearly the same, omitting the first process of spinning, and reducing the turns to four or less in the second or throwing, to obtain the looseness of structure that will yield the desired end.

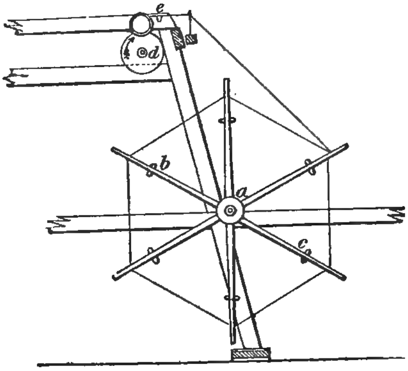
The first step taken with raw silk is to separate the "book" or "moss" into knots, and sort these into lots according to their respective fineness, as well as can be judged by the eye. This separation is, however, a very imperfect one, as the unaided eye is scarcely equal to discriminating between the differences in the thickness of the threads; and in addition, there are many knots that contain both fine and coarse thread, changing to one or the other in the space of a few yards. After this preliminary, the hanks are dipped for a short time in a solution of soap and water, to soften the gum upon the fibre, which renders it more pliable and easy to wind, for which operation it is then ready.

Winding.—The winding-machine, Fig. 1226, is generally arranged in the swifts to take either Italian, Chinese, or Japanese reeled silks. It is a very simple machine, consisting of little more than the framework, the swifts, and a roller carrying friction-drums, on which the bobbins for the reception of the silk revolve. These, being duplicated, render the machine double. Fig. 1227 shows a section of the working parts. The swift *a* is composed of a hub or nave of wood, into which are inserted six pairs of thin lancewood rods *b*. Each pair of rods is connected near the top by thin cords; to keep the latter at proper tension, a wedge *c* is put below the cords, and presses the lancewood rods apart. Both cords and rods can be easily adjusted to receive any size of hank. Each swift has a small weight suspended upon the hub, in order to prevent its too rapid revolution, and to impart the requisite tension to the thread in process of winding. The bobbins are fixed upon

1226.

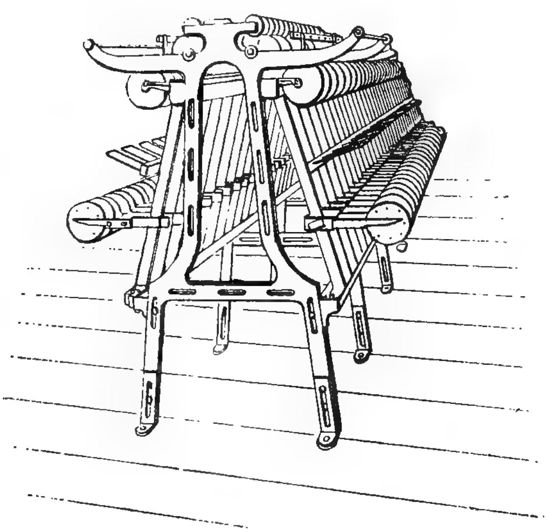


1227.



spindles having heads or small rollers, and are actuated by friction-wheels *d*. A slot *e* is prepared for the spindle when out of contact with the friction-driver. Fig. 1228 exhibits another form of winding-machine.

1228.

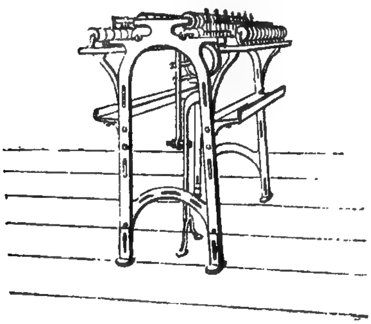


A "slip" or hank having been put upon the swift, the end of the thread is found, and the winder, wetting it in her mouth, casts it upon the bobbin, to which it adheres; this being placed upon the driver, the winding commences, the thread having been previously inserted into the curl or ring of the guide-wire, fitted into the traverse-rail, whose lateral movement winds the thread regularly upon the bobbin. When the hank is wound off, or the thread breaks, the end is joined to that upon the bobbin by a peculiar knot formed to prevent slipping in subsequent operations. The guide-rail or traverse-bar is operated by elliptical wheels, or heart-shaped cams, in order to make a bobbin of a good form. To prevent waste of material and loss of time, the winding is arranged so that each successive layer shall obliquely cross the threads of the preceding one. Winding-frames generally contain 30–40 swifts to each side of the machine.

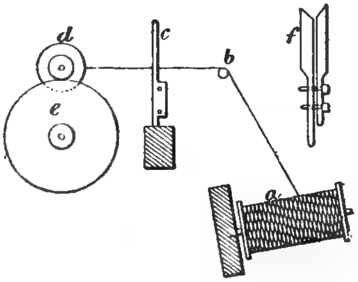
Cleaning. — The cleaning-machine, Fig. 1229, which is often called the redrawing frame, to which the bobbins from the winding-frame are now conveyed, is of similar construction to the preceding machine. For the swifts of the winding-frame, is substituted a bobbin-board, fitted with pegs to hold the bobbins; whilst in place of the guide-wires of the traverse-rail, the thread passes between two vertical steel blades, whose edges are set so closely together as to detect and arrest any knots, slubs, or other defects of a gross kind that would interfere with the perfection of the subsequent stages of the work. The distance between the edges of these blades can be adjusted with great nicety by means of screws. Fig. 1230 shows the working parts in section. The bobbin *a* from the winding-machine is placed upon the pin in the board, so as to allow of easy revolution in unwinding. The thread is conducted over the carrier-rod *b*, next passing through the cleaner or vertical blades *c*, and thence upon the bobbin *d*, actuated as before by the friction-wheel *e*. The cleaner is fixed in the traverse-bar or guide-rail. An enlarged front view of the cleaner is shown at *f*.

Cleaning is not the only purpose of this process; an object of equally great importance is the "sizing" of the silk, a word implying a very different process from that which the same term indicates when used in connection with the cotton trade. It means the still further elimination of the irregularities of raw silk, enabling the manufacturer to produce an even fabric. As the winding proceeds, the attendant is carefully observing the threads, and when one of these begins to deliver a thread finer than required, it is broken off, and the bobbin is moved to the right; if a coarse thread comes off, it is similarly moved to the left. When the process is completed, the silk is thus assorted into two sizes, which are marked firsts and seconds. When it is desired to secure the most perfectly even threads, this process is repeated several times, though all of them constitute but a very imperfect remedy for careless reeling from the cocoon.

1229.



1230.

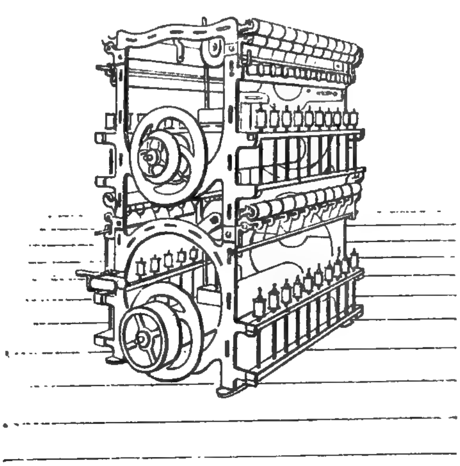


In this form, the silk is technically called "dumb singles," because, being in the gum, it does not show up its lustre. Though it has no twist, it is sufficiently strong for the warp purposes of particular fabrics, such as gauzes, bandanas, &c.; it is sometimes used for weft purposes also. In both cases, it must be used in the natural gum, as if it were attempted to clear it or dye it, to bring up the lustre or improve the colour, it would be rendered too soft and flossy for use. The silk is therefore cleared in these cases in the fabric, being boiled or dyed after manufacture. It is, however, sometimes "stained" by immersion in a cold dye-bath, when it is necessary to get a coloured thread; but in this case, the colour is neither so fast nor so lustrous as when treated in the other manner.

Spinning and Doubling.—After the cleaning and the sizing process of the last stage, the thread is ready for the spinning-machine, to which the bobbins are conveyed.

Assuming that organzine is required, the process is to spin or twist the "single" thread, composed of the filaments reeled together from the cocoon. In this case, it is customary to put about 15 turns an inch for most descriptions of work, though, in many instances, this number is departed from, according to special requirement. In some cases, when singles are intended for organzine, 60 turns an inch are put in.

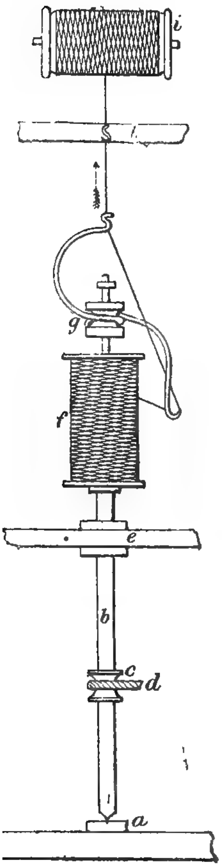
1231.



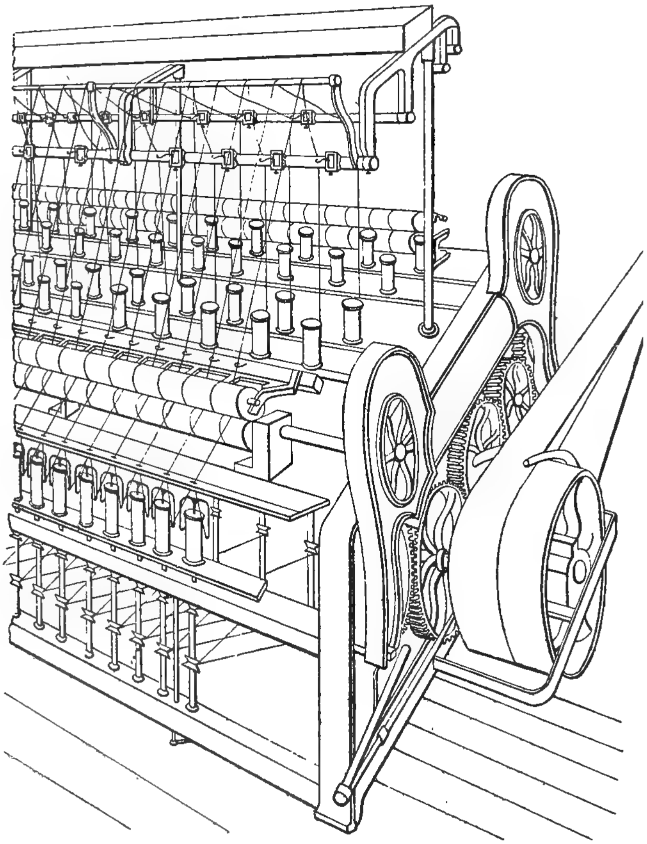
The spinning-machine, Fig. 1231, usually contains two tiers of spindles, one above the other, the whole amounting to several hundred. The driving-shafts, one for each tier, carry a cylindrical tin drum extending the length of the frame. This drum actuates the spindles by means of driving-bands, one for each spindle, which pass around it, and thence around the wharve upon the lower part of the spindle between the bolster and the footstep. Fig. 1232 shows the details of one of these spindles and its mountings: *a* is the footstep in which the spindle *b* revolves, carrying the wharve *c* for the reception of the driving-band *d*. Midway in its height, the spindle passes through a bolster-rail *e*, fitted with brass bearings, in which it revolves. Just above the bearing, the spindle is tapered for the reception of the bobbin, the smallest diameter being at the top. The bobbin *f* from the cleaning-machine, being adjusted upon the spindle, is firmly held upon the tapered part, and above it is mounted the flier *g*, composed of a small wooden boss, having a groove around its circumference, into which the wire forming the flier-arms is bent and secured. The extremities of this wire are curved to form eyelets for the reception of the thread. The traverse or guide-rail *h* is also fitted with eyelets.

In the process of spinning, the thread, both single and double, is conducted from the bobbin *f* through the lowest eyelet of the flier, around the limb *h*, through the upper eyelet, as well as that of the traverse-rail, and thence upon the bobbin *i*, whereon it is wound in crossed layers, as before, and for the same purpose. It will be observed that the course of the thread in silk-spinning is the reverse of that in other textile fabrics, being delivered instead of received by the bobbin upon the twisting-spindle. Should the thread be drawn from the bobbin *f* with the spindle at rest, one turn or twist would be imparted to it for every revolution drawn off. Suppose, however, the spindle to be making 6000 rev. a minute, and the draft of the bobbin to be 400 in. in the same time, it is obvious that this will give 15 turns for 1 in. of the thread, plus one turn for every rev. of the thread drawn from the bobbin required to yield 400 in. When single is being spun for organzine, and more twist is required, the draft of the bobbin *i* is diminished in proportion.

1232.



1233.



In silk-spinning, the flier is sometimes dispensed with, its chief use being to protect the thread from injury by friction during delivery from the bobbin, which some think is a more imaginary than real risk. As will be seen from the description of the machinery already given, and the nature of the silk filament or cocoon thread, the working of silk, especially in the throwing department, is exceedingly simple, consisting only of winding and twisting, and hardly affording much scope for the ingenuity of the mechanical inventor. Hence it is that improvements are comparatively rare and unimportant.

A machine, however, has recently been introduced for spinning or twisting purposes which is a considerable improvement upon preceding ones, owing to its productive capacity per spindle being double that of most others, thereby enabling considerable economy to be effected in space, waste, shafting, gearing, belts, buildings, and labour.

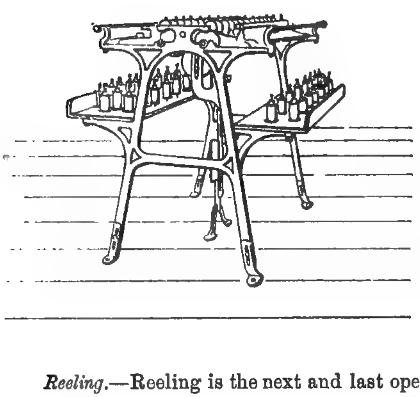
The structure of this machine, Fig. 1233, which can be adapted to any fibre, more nearly approximates to that of the bobbin-and-fly-frames, as used in cotton industry, than to machines employed in the silk manufacture. Instead of the bobbins containing the material to be treated, reposing in a bank or creel on pegs, as usual, the machine is fitted with a creel or set of spindles which carry the bobbins containing the threads to be twisted, and these spindles are made to revolve at a great speed. Thus, running at the same rate as the front or twisting-spindles, which may be assumed to be 4000 rev. a minute, half the twist is put in before the yarn reaches the draft-rollers, when it becomes subject to the action of the front spindles. These working at the usual speed, and having only half the task to perform, it enables the rollers to be put on double speed, thus filling the bobbins in half the time, and ensuring a double production.

The ordinary spindle carries an extra wharve, from which, power is transmitted by means of a band to the creel spindle, mounted in rails. On the top of this spindle, is placed the bobbin containing the threads to be twisted. Being fixed on the spindle, the bobbin revolves with the spindle, which puts in half the required twist before the thread reaches the rollers. As this result is accomplished without any increase of the speed of the spindle, the advantages of the process will be obvious. It enables the production of every spindle to be doubled, whilst cost in wages is not increased. Only half the space is required, as compared with the ordinary method, the shafting, gearing, complementary fittings, cost of supervision, and all other expenses, being obviated.

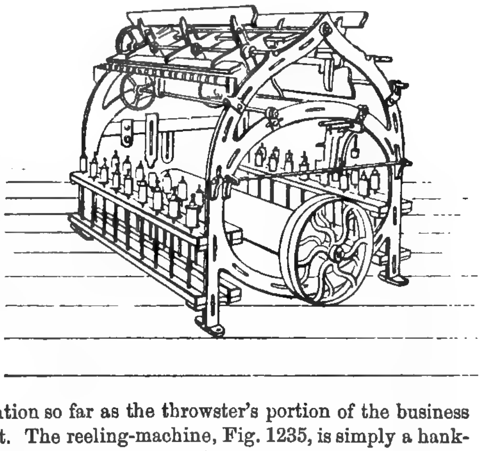
This machine is known as "Murray's patent," and is made solely by Thomas Unsworth, of Manchester. When it is used, the bobbins are prepared for it preferably upon the winding-doubling-machine of the same maker, described in the article on Rope (see p. 1595). The single having thus received the twist necessary for forming organzine, in which two strands of the single are combined, it is taken to the doubling-machine, Fig. 1234, in which two threads or more if required are wound upon one bobbin in a manner as perfectly parallel as possible, in order that all may be of exactly the same length, which, in the subsequent operation of twisting, is requisite to produce organzine of the best quality. It differs so little from the machines previously described, that it calls for no further notice.

Having been doubled, the threads are again brought to the spinning-frame, and, for organzine, are twisted about 8 times an inch, but in a direction opposite to that of the first twist. When tram is required, this is the only twisting or spinning to which the thread is subjected, and in this it only receives about 4 turns an inch, the result being that a soft spongy thread is formed, well adapted to cover the warp threads, and show up the lustre of the fibre.

1234.



1235.

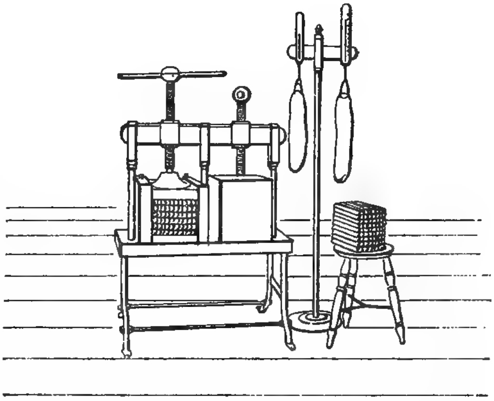


Reeling.—Reeling is the next and last operation so far as the throwster's portion of the business is concerned, except the packing for the market. The reeling-machine, Fig. 1235, is simply a hank-winding machine, in which the silk, as it finally leaves the spinning-frame, is wound into a form to fit it for the operations of boiling, to clear it from the natural gum, and dyeing, in which the richest colours are imparted to it previously to its being woven or otherwise fabricated into the numerous articles of luxury for which from the first it has been designed. This machine, like all the others illustrating this article thus far, with the exception of Fig. 1233, is made by Enoch Rushton, Macclesfield, and is fitted with his self-acting count-guider and stop-motions. The former registers in yards the exact length of each skein; when the length required has been reeled, the guider makes a lateral movement, and alongside the first skein runs another the same length, and so on in succession until the reel is full, when it stops the machine. By this means, perfect uniformity in the length of skein or hank is secured. These skeins, being afterwards carefully weighed on dramming- or deniering-machines, being all of one length, can be "sized" or assorted with great correctness.

After silk is thrown, it is generally reeled into skeins of 1000 yd., and to ensure regularity, these are assorted as just described, and arranged in lots, ¼ dram difference in weight defining the lots. Thus, if 1 skein weighs ¼ oz. = 4 dr., it is denominated 4-dram silk; if ¼ dr. lighter, it is 3¾-dram silk, &c. Where the greatest regularity is desired, and the expense is not an obstacle, silk is reeled into half-skeins of 500 yd., or quarter-skeins of 250 yd., and then carefully weighed and assorted as before. This process is called "half-" and "quarter-sizing." In France, the skein measures 520 yd., and is weighed in *deniers*, the *denier* being equal to 0·825 gr.

When the process of assorting or sizing has been completed, the silk is gathered into hanks, twisted into knots, arranged in bundles, and pressed in the manner shown in Fig. 1236.

1236.



Silk, besides being thrown into the form of organzine and tram for weaving, is made to assume numerous other special forms and designations, according to requirement. Amongst these, may be mentioned embroidery-, fringing-, sewing-, knitting-, and machine-silks. There is, however, no essential difference in them, all being simply combinations of the number of threads needed to give the thickness, and of variations in the twist required to obtain the effect.

Silk at this stage becomes a mercantile article, known as "thrown silk," and as such is sold to manufacturers, who weave or otherwise work it into the forms in which it is presented to the consumer. In many instances, the processes of throwing and manufacturing are combined in one establishment.

The silk thus usually comes into the hands of the manufacturer in the form of "hard" silk, as it is technically called, when in the gum previous to boiling. Before dyeing, it always undergoes this operation, which greatly changes its appearance. In the gum or natural state, it is dull, hard, and wiry, and might easily be mistaken for several other fibres. Boiling reduces its weight nearly one-third, softens it, and develops its lustre, bringing out its wonderful brilliance. It then becomes "soft silk." It is manufactured in both these states, though comparatively rarely in the former.

In dyeing, the weight of the dye-stuffs partially restores the loss caused by the removal of the gum; but advantage is very often taken of this process to load the material heavily with chemicals, sometimes to the extent of 5–6 times the original weight. In some cases, as for instance when the silk has to be manufactured into fringes, and is required to hang heavily, this weighting is advantageous in obtaining the effect; but as a general rule, all weighting may safely be regarded as adulteration, and intended to cheapen the cost of production. It is certain that the chemicals used to weight it injure its strength and durability, and, in the end, enhance the cost.

Spun Silk.—In silk growing and the subsequent manipulation of the material in transforming it into articles of utility, it will be obvious that a considerable quantity of waste material must accumulate. The floss-silk, or outer covering of the cocoon; the perfect cocoons reserved for propagation, and which are pierced by the insect; badly formed, entangled and otherwise defective ones; the bottoms of cocoons when the usable filament has been wound off; and the loose fibre produced in after stages of working, all contribute to the stock of waste. The aggregate weight of material obtained in this manner forms a large percentage of the entire weight of the crop of cocoons. When it is considered that all silk-producing countries are sources of supply, it will be seen that the bulk of fibre of this description placed at the disposal of manufacturers is very great.

Until about 1857, this waste was the most useless bye-product obtained from any of the textile industries. The world is indebted for its utilization to Samuel Cunliffe Lister, of Manningham, near Bradford, by whose mechanical genius and enterprise it was made to serve a useful purpose.

The manufacture of silk-waste differs radically from that of net or thrown silk, being much more akin to the manufacture of worsted. The different varieties of silk, such as Italian, Chinese, Japanese, and Bengal, are kept apart, owing to their varying qualities. But the waste from all may be worked together, though it is usual to separate them according to shades of colour. The classification is generally into two shades, yellow and white; the former is termed Italian, and the latter Chinese. Sometimes the yellow tint of the first-named sort is removed or covered by a process of dyeing, which imparts to it the whiteness of the latter. Should the material thus sophisticated be boiled at a subsequent stage, the original tint will reappear, and may cause defects in the fabric into which it has to enter. It is therefore important for the manufacturer to know when it has been subjected to such treatment.

On the Continent, it is customary for spinners to work waste silk with the gum in it, in which state it is known as "Schappe silk." English manufacturers, however, usually prefer to clear the gum from it by boiling. This is the first process to which it is submitted. After boiling, the mass presents a rich lustrous appearance, but thoroughly entangled.

It is now ready for the "breaker," a machine allied in its function and structure to the "rag-devil" of the shoddy manufacture (see Woollen Manufactures), which tears, breaks, and disentangles the fibrous mass. The latter is by this means reduced to lengths from 12 in. downwards, by which it is fitted for the process of combing.

The principle of combing is similar to that employed in the manipulation of long wool for the production of worsted, with the modifications rendered necessary by the different nature of the material. In combing silk-waste, the material is separated into several portions, each of a different length of staple, and the combing-machine is consequently arranged to obtain this result. The first draft yields a staple about 12 in. long, which can be spun into 100's–140's single thread; this is called "first drafts." The next in length is called "second drafts," and is suitable for the production of 70's–90's. There are several successive ones, named thirds, fourths, fifths, &c., which are utilized in the production of coarser yarns. The short fibre remaining after the abstraction of the preceding lengths of staple, and which is too short to comb, is called "silk-noil," and is relegated to the silk carding-machine, which differs very little from those for cotton or wool. It is subsequently treated in the same manner as those fibres, the product being finally known as "carded spun silk," or "short spun silk," to distinguish it from combed silk-yarn, which is called "long-spun" or "patent silk." The perfection to which the combing process has been carried leaves very little material available for carding purposes, and the yarn produced from the latter is disappearing; it is going out of favour also from another cause, namely, its lack of lustre as compared with that produced from the combing process.

The different lengths of silk "top" produced from the raw material by the comb are further drawn and combed to form a "sliver," a number of these being combined and drawn into one, to eliminate irregularities and secure perfect uniformity. This process is repeated several times according to requirement, and the quality of yarn it may be desired to obtain. The sliver is next passed through a roving-frame, in which it is attenuated to the required degree, and wound upon a bobbin for the supply of the next machine, the spinning-frame, constructed on the principle of the cotton throstle-machine. The short-spun or carded silk is spun upon the mule (see Cotton Manufactures, pp. 753–60).

Yarns spun from silk-waste are not so perfect as those obtained from other fibres. The combing and carding processes are insufficient to thoroughly cleanse the material from impurities, lumps and rough bits remaining on the thread to a large extent. A simple and ingenious process has been invented, called "improving," by which the thread is very much cleared and improved in appearance. When the bobbins have left the spinning-machine, they are taken to another machine, and the thread is run from one bobbin to another, passing around several revolving spindles fixed on the cleaning-bar, and arranged so that the travelling thread rubs against itself, the friction clearing away the lumps and roughnesses not imbedded in the thread. The yarn is remarkably improved by this operation. When it is required of particular count, and has to be submitted to this process, it must be spun considerably heavier, as the weight is much diminished by the friction and loss resulting.

Still another process remains. Spun silk can never be made to equal thrown silk in its lustre, but it is greatly improved by the "gasing," in which operation the thread is run rapidly through a jet of gas, which burns off the extremities of the fibres that project from the surface of the thread. When these are cleared away, the light has direct access to, and is reflected from, the surfaces of the long fibres laid parallel in the thread, by which its lustre is greatly increased.

For purposes in which the strength of silk only is required, both the above processes are omitted, as, owing to the reduction of the weight consequent thereon, and the cost of labour, the price is enhanced fully 2*s.* a lb. Where, however, a lustre approximating to that of net silk is required, the yarn is always submitted to both of them.

Spun silk is more lustrous than perhaps any vegetable or animal fibre with which it comes into competition, with the exception of thrown silk, and being capable of yielding uniformly level and round yarns, which cannot be obtained from thrown silk, it possesses advantages for some purposes even over the latter. Owing to this quality, a good sightly fabric can be produced in the power-loom, free from the "stripey" character often seen in thrown-silk goods, even when made in the hand-loom, and which defect originates in the irregular thickness of thrown-silk threads. Combed spun, or patent silk, has come into general use for sewing-machine purposes, having of late years quite superseded thrown silk in that sphere. It has also been adapted for use in the manufacture of many other-articles, amongst which may be mentioned cords, braids, fringes, tassels, heavy laces, and numerous smallwares; fabrics such as "cut-ups" for tie and scarf purposes, dress goods, handkerchiefs, mufflers, &c., and in these and other capacities fills a very useful place amongst textile fabrics.

Weaving.—The weaving branch of the silk manufacture as an art has been carried to the highest degree of perfection yet attained in any of the textile industries. The fineness, strength, lustre, and affinity for dyes, of the raw material, are qualities that cause it to lend itself with great facility to the purposes of the designer, and the requirements of the weaver. The rich lustre of a black cachemire, contrasts finely with the dense black of a velvet fabric, and the latter again with the sheen of a satin. Figured damasks, produced by the jacquard attachment, show another phase of the excellent results attained in the manipulation of this premier textile fibre, whilst the brilliant hues that can be obtained when the resources of tinctorial art are called in to aid, demonstrate that practically when wealth is at command there is no limit to its use for decorative purposes. To show what can be produced, portraits, pictures, landscapes, and artistic effects have been wrought of such perfection and beauty as to vie with the products of the pencil or the graver. These highest results are mainly the outcome of the handicraft form of the industry, as, owing to facts previously explained, the material does not surrender itself easily to the requirements of automatic mechanism. With the development of invention and increasing skill, some of the difficulties yet encountered will no doubt in the early future be obviated; but even without improvement in that respect, accomplished results are so excellent that only the relatively high price of silk articles precludes a great extension of consumption. Growing wealth on the one hand, and extended sericiculture on the other, will do much to remove this obstacle. By many persons highly qualified to form correct opinions on the matter, this view of the future is regarded as very likely to be realized.

Statistics.—The manufacture of silk in this country during the past twenty years has continuously diminished. The causes which have led to this are not far to seek. The extraordinary development of other industries greatly drained the labour supply formerly available, enhancing the value of that which remained ; legislative enactments in the interests of the operatives further hampered the trade when brought into competition with the unrestricted, unprotected, and cheap labour of the Continental states; and the final blow was the sudden abolition of the import duties on foreign silk goods on the conclusion of the first treaty of commerce between France and this country. From the check then received, the silk industry of this country has never recovered, and a steady diminution of its extent and importance has since taken place.

The following table exhibits a summary of its condition in 1879 as shown by a Return to Parliament. A comparison is also afforded with its state in 1874.

	No. of Factories.	No. of Throwing Spindles.	No. of Doubling Spindles.	No. of Power Looms.	No. of Power-loom Weavers.	No. of Persons employed.		
						Males.	Females.	Total.
England and Wales ..	700	832,748	166,289	12,335	—	11,702	28,514	40,216
Scotland	5	9,790	10,112	211	—	69	548	617
Ireland	1	—	—	—	—	102	50	152
Total in .. 1879	706	842,538	176,401	12,546	No return.	11,873	29,112	40,985
Total in .. 1874	818	1,114,703	221,708	10,002	6,080	13,171	32,388	45,559

The figures of these returns give the numbers of workers subject to the enactments of the Factory Acts. Much of the silk industry has, however, remained a domestic occupation, for which it is peculiarly suitable. Those employed in this section do not therefore fall within the enumeration. They form fully one half: if the particulars for the above periods be each multiplied by two, an approximately accurate result will be obtained.

Our imports of silk manufactures from countries out of Europe were valued at 330,744*l.* in 1879, and at 239,852*l.* in 1880 ; and from countries in Europe, at 12,511,174*l.* in 1879, and 13,085,083*l.* in 1880.

Our exports of silk manufactures in the year 1880 were as follows. Broad-stuffs of silk or satin, 3,746,830 yd., 710,365*l.*, nearly half being to France, and almost a quarter to Australia. All-silk handkerchiefs, scarfs, and shawls, 409,189*l.*, about three-fourths being to Bengal and Burma. Silk ribbons, 123,429*l.*, more than half to Australia. Silk lace, 109,953*l.* Unenumerated all-silk goods, 250,807*l.* Broad-stuffs of silk and other materials, 2,471,680 yd., 302,355*l.* Other kinds of goods containing silk, 124,561*l.* Grand total value, 2,030,659*l.*

R. M.

(See Cotton Manufactures ; Silk ; Woollen Manufactures.)

SKINS (Fr., *Peaux*; Ger., *Häute*).

Skins whose industrial value depends upon the attached hair or feathers, rather than upon the corium itself, have been described under Feathers (pp. 904–9) and Fur (pp. 1029–33); there remain for description in the present article those skins and hides (the latter term being commercially applied to the skins of the larger mammals) which are valued for themselves. As the structure and morphology of hide have been treated of at length in Leather (pp. 1213–40), the present article will be concerned chiefly with the trade in skins, which possesses no small importance. Many of the statistics relating to skins are collective, and not specific; these will be grouped under the heads of the respective countries, after all accessible details have been given upon each kind of skin.

Alligator.—In the S. United States, notably Florida, the supply of alligator-skins amounts to many thousands annually, and the "farming" of the reptiles for their skins is even spoken of. The principal market for them is Europe, but no statistics of the trade are published.

Armadillo.—The skins of this animal were exported from Brunei (Borneo) to Singapore to the value of 121 *dol.* (of 4*s.* 2*d.*) in 1879.

Ass.—Hankow exported 2402½ *piculs* in (of 133⅓ lb.) of asses' skins in 1878, and 1068 *piculs* in 1879.

Buffalo.—Manilla (Philippines), in 1878, exported 379 tons of buffalo-skins, value 12,130*l.*, and 274 tons of cuttings, 6579*l.* Hankow exported 1091 *piculs* in 1878, and 1238 in 1879. Brunei (Borneo) sent 1362 *dol.* (of 4*s.* 2*d.*) worth to Singapore in 1879. The approximate London market values of buffalo-skins are:—Batavia, 4–7*d.* a lb.; Bengal, 3–6*d.*; other sorts, 2½–6½*d.*

Calf.—Hamburg exported to Great Britain of calf and other skins in 1876, 20,731 cwt.; in 1877, 27,550; in 1878, 14,583; and in 1879, 19,287 cwt. The Hawaiian Islands sent 168 pieces to Germany in 1879. Christiania shipped 31,000 *kroner* (of 1*s.* 1½*d.*) worth to Great Britain in 1878, and 300 *kr.* in 1879. The exports from Archangel (including seal) in 1878 were 335 pieces to Holland, and 23,108 to Germany, total value 2343*l.* Honolulu, in 1878, exported 651 pieces, being 500 to Germany, 135 to China, and 16 to the United States. Memel, in 1879, sent landwise over the Russian frontier for German markets, 34,400 pieces, value 5450*l.* The approximate London market value of calf-skins is 15–34*d.* a lb.

Deer.—San José (Costa Rica) exported 21,121 lb. in 1878. Kiungchow (China) exported 17,544 pieces, value 541*l.*, in 1879. Ciudad Bolivar (Venezuela), in 1879, sent 77,305 pieces (168,176½ lb.) to New York, and 14,695 pieces to Germany. Guatemala, in 1879, exported 2353 pieces to Germany, 693 to New York, and 100 to Belize. Panama shipped 765*l.* worth of deer and other skins to the United States in 1879. Costa Rica exported 82,168 lb. in the year ended April 30, 1879. Puerto Cabello (Venezuela), in 1879, shipped 2466 *kilo.* (of 2·2 lb.) to Great Britain, 11,619 to Germany, 6182 to the United States, and 1281 to Holland. The Commercial Society of Mozambique sold 41 deer, 391 buck, 2168 blesbok, and 3071 other antelope skins at Rotterdam in June 1876. The approximate London market values of deer skins are: Blesbok, Cape, 6–17*d.* a lb.; Deer, E. Indian, 22–50*s.* a doz.

Dugong and Manatee.—The skins of these animals, more important perhaps as oil-yielders (see p. 1365), are smooth, bluish-black in colour, and nearly 1 in. thick. They are well adapted for machine-belting. About 50 are shipped annually from Queensland.

Fish.—The skins of many true fish are strong, firm, and durable, and capable of wide industrial application. Flat-fish give a skin suitable for gloves and fine upper leather. Sole-skins will make purses. Thornback-skins may replace sandpaper for cabinet-making purposes. Eel-skins will make strong braces. Siluroid skins are largely converted into gloves at Colborn, in Canada. Torsk-skins have been made into shoes. Some Red Sea fish-skins are utilized for sandal-making in Egypt. Burbot-skins form durable bags used by some Tartar tribes. Salmon-skins make a leather as tough as wash-leather, and about the thickness of dog-skin, the scale-marks giving a neat pattern; they are employed in clothing by some of the peoples of E. Asia. The skins of the sea-angel, thorny shark, tiger shark, and some skates are used for burnishing, and for covering boxes. Ray-skins are converted into shagreen; France imported 18,000 lb. of them in 1863, chiefly from Portugal. The blue dog-fish gives a skin which is widely used for polishing.

Goat and Kid.—Our imports of undressed goat-skins in 1880 were:—937,691, 113,051*l.*, from British S. Africa; 345,217, 41,155*l.*, Bengal and Burma; 302,590, 23,827*l.*, Turkey; 220,206, 22,861*l.*, Madras; 205,122, 24,595*l.*, Belgium; 77,151, 11,747*l.*, France; 74,464, 9969*l.*, Germany; 61,882, 5368*l.*, Egypt; 31,895, 2989*l.*, Bombay and Sind; 284,842, 36,418*l.*, other countries; total, 2,541,060, 291,980*l.* And of undressed in the same year, from:—Madras, 5,829,608, 626,232*l.*; Bombay and Sind, 1,369,137, 123,633*l.*; Bengal and Burma, 796,214, 90,252*l.*; France, 356,153, 72,335*l.*; Aden, 215,992, 20,424*l.*; Turkey, 113,039, 14,863*l.*; Holland, 107,588, 19,324*l.*; other countries, 138,444, 18,699*l.*; total, 8,926,175, 985,762*l.* The total number is 11,467,235, as against 8,051,112 in 1876. Our imports from British India rose from 55,929 undressed in 1876 to 597,318 in 1880; and of dressed, from 6,127,900 in 1877 to 7,994,959 in 1880. Ciudad Bolivar (Venezuela) sent 317 pieces (284 lb.) to New York in 1879. Tripoli exported 7000*l.* worth in 1879, and 3000*l.* in 1880. In 1880, a number of raw goat-skins were sent from the Marche and Romagna to the United States, weighing about 1½ *kilo.* (of 2·2 lb.) each, and to be used chiefly for ladies' shoes and pocket-books. Shanghai, in 1878, exported 164,285 pieces. Tangier, in 1879, sent 12 cwt., 60*l.*, to Great Britain; 3637 cwt., 18,185*l.*, to France and Algiers; 10 cwt., 50*l.*, to Spain; total, 14,636 doz., 18,295*l.*; and 3046 cwt., 13,707*l.*, in 1880. The Hawaiian Islands, in 1879, shipped 24,940 pieces to the United States (Pacific ports). In 1879, Christiania exported 65,700 *kroner* (of 1*s.* 1½*d.*) worth of goat and sheep skins to Great Britain. The shipments of goat and kid skins from the French E. Indies to Great Britain fell from 5500 in 1876, to 4894 in 1877, and 300 in 1879, with none since. The shipments from the Cape to Great Britain were 794,637 in 1878, 657,509 in 1879, and 934,810 in 1880. Cadiz, in 1877, sent 404 *kilo.* (of 2·2 lb.) of kid skins, value 84*l.*, to Great Britain, and 3866 *kilo.*, 805*l.*, to France. Puerto Cabello (Venezuela), in 1879, despatched 28,684 *kilo.* to Germany, 124,964 to the United States, 14,295 to France, and 18,536 to Holland. Honolulu sent 64,525 pieces to the United States in 1878. Samsoun (Turkey) exported 130,700 *kilo.*, 6796*l.*, to France in 1878. The Cape exports fell from 1,478,761 pieces in 1874, to 687,570 in 1879. Memel sent by sea 7 cwt., 73*l.*, in 1879. Tientsin (China) exported 38,107 *piculs* (of 133⅓ lb.) in 1879. Mogador (Morocco) forwarded 112,974 doz., 59,243*l.*, to Marseilles in 1878, and 8407 bales, 48,000*l.*, in 1880; these skins are used for the manufacture of morocco leather, for which they are peculiarly suitable, owing to their fineness of grain, caused, it is said, by the rich diet, consisting of the fruits of the argan tree (see Oils, pp. 1377–8). The approximate London market values of goat-skins are:—E. Indian, 4–15*d.* a lb.; best tanned, 2*s.* 4*d.*–3*s.* 8*d.*; inferior to good tanned, 9*d.*–2*s.* 5*d.*; Cape, best, 11–18*d.*; Cape, inferior to good, 8–14*d.*

Horse.—Shanghai exported 458½ *piculs* in 1878. Rio Grande do Sul exported 10,714 pieces salted, and 601 dried, in 1879. The approximate London market values of horse-hides are:—English, 9–14*d.* a lb.; River Plate, 6–21*s.* a hide.

Kangaroo.—The skins of this animal are largely exported from Australia and Tasmania, forming some of the most pliable leather known.

Lamb.—The exports from Asterabad (Persia) viâ Gez in 1879 were 788 bales Bokharan, 60,613*l.* Calamata and Messenia (Greece) produced in 1880, 137,500 lb., 2680*l.* Dedeagatch (Turkey), in 1878, exported 500 bales of lamb and kid skins, value 4000*l.* The exports from Ancona (Italy), including kid and rabbit, in 1878, were 609,826 *kilo.* (of 2·2 lb.) to Italy, 41,480 to Austria, 2714 to Germany, 2655 to Greece, 19,486 to England, 3180 to Turkey; total, 679 tons, 50,321*l.* Tientsin (China), in 1879, shipped 35,008 *piculs* (of 133⅓ lb.).

Llama.—The skin of the llama is growing in importance in Parisian shoemaking. It weighs on an average 6 lb., and contains 18 sq. ft. of leather, costing about 1*l.* The source of supply is the Peruvian Andes.

Ox and Cow.—Coquimbo (Chili) exported 4709 ox-hides in 1879. Santos (Brazil) in the year ending Sep. 30, 1879, exported 316,940 *kilo.* salted, valued 5800*l.*, and 1282 dried, 25*l.* The shipments from Christiania to Great Britain fell from 47,500 *kroner* (of 1*s.* 1½*d.*) worth in 1877, to 3500 *kr.* in 1879. San José (Costa Rica) despatched 449,870 lb. in 1878. The exports from the Cape, including cow, fell from 150,875 pieces in 1878, to 104,281 in 1879. Rio Grande do Sul, in 1879, shipped 455,315 pieces salted, and 499,960 dried. Of cow-hides, Hankow exported 35,265 *piculs* (of 133⅓ lb.) in 1878, and 21,063 in 1879. The Kiungchow exports (including buffalo) in 1879 were 490 *piculs*, 818*l.* From Shanghai (including buffalo) went 26,070 *piculs* in 1879. Chinkiang fell from 7262 *piculs* in 1877, to 3974 in 1878, and none in 1879. Memel, in 1879, sent away by sea, 75 cwt., 136*l.*; and over the Russian frontier for German markets, 3000 pieces, 3000*l.* The approximate London market values of ox and cow hides are:—Buenos Ayres and Monte Video, 1st dry, 9–10½*d.* a lb.; 2nd dry, 7–8½*d.*; best light, 8–9½*d.*; salted, 5¼–7¾*d.*; Brazil, dry, 7–10½*d.*; dry-salted, 4½–9*d.*; W. India, salted, 3½–7*d.*; United States, salted, 3½–6½*d.*; E. India, best, 4–13*d.*; 2nd, 1¾–11¼*d.*; 3rd and 4th, 1¼–9*d.*; Australian, salted, 2¾–6*d.*; Cape, wet salted, 2½–7½*d.*; Continental, salted, 3¾–5*d.*; English, 2¾–7*d.*

Seal.—Our imports of seal-skins in 1880 were from:—British N. America, 287,449, 82,781*l.*; United States, 162,189, 425,705*l.*; N. whale fisheries, 54,381, 11,656*l.*; Norway, 54,005, 12,204*l.*; Uruguay, 10,900, 30,180*l.*; other countries, 84,352, 60,752*l.*; total, 653,276, 623,278*l.* In 1879, the total was 964,208 skins. The exports from Christiania in 1879 were 74,090 pieces; to Great Britain, the value was 254,400 *kroner* (of 13½*d.*) in 1878, and 172,900 *kr.* in 1879. Our total imports from Norway rose from 29,912 pieces in 1877, to 63,540 in 1878, and receded to 54,005 in 1880. From the Cape, they were 11,065 in 1877, 15,128 in 1879, and 7731 in 1880. And from Newfoundland, 413,057 in 1879, and 253,656 in 1880. The approximate London market values of seal-skins (not fur seals) are 1*s.* 9*d.*–10*s.* 6*d.* each for Newfoundland, and 2–11*s.* for Greenland.

Sheep.—Our imports of undressed sheep-skins in 1880 were from:—British S. Africa, 1,850,731, 241,915*l.*; Argentine Republic, 1,245,703, 217,592*l.*; France, 909,828, 136,217*l.*; Australia, 816,231, 124,430*l.*; Germany, 405,101, 51,914*l.*; Belgium, 336,388, 40,201*l.*; Turkey, 246,643, 20,821*l.*; Uruguay, 131,543, 18,102*l.*; other countries, 844,697, 92,731*l.*; total, 6,786,865, 943,923*l.* Dressed, in the same year, from:—Madras, 2,151,533, 192,480*l.*; Australia, 1,626,355, 81,623*l.*; Bombay and Sind, 600,347, 46,089*l.*; France, 560,103, 68,316*l.*; Bengal and Burma, 160,094, 26,851*l.*; other countries, 446,116, 55,555*l.*; total, 5,544,548, 470,914*l.* Bosnia Serai, in 1879, exported about 10 tons. Shanghai, in 1878, 50,285 pieces (including lamb). Coquimbo (Chili), in 1879, 45 tons (including goat). Bagdad, in 1878, 86,351 pieces, 4071*l.*, to India and Europe (including lamb). Falkland Islands, 1940*l.* worth in 1879. Cape, 1,480,875 pieces in 1879. Hankow, 7606 pieces, 9276*l.*, in 1879. Tientsin, 206,777 *piculs* (of 133⅓ lb.) in 1878, 8737 in 1879. Mollendo (Peru) 79 *quintals* (of 2 cwt.) in 1878. Mogador, in 1880, 15 bales, 80*l.*, to Great Britain; 345, 1700*l.*, to France; 2, 3*l.*, to Spain. Our imports from the French E. Indies have fallen from 5600 pieces in 1876, to 3762 in 1877, 410 in 1879, and none since; from Italy, from 339,973 in 1876, to 39,751 in 1880; from European Turkey, from 230,922 in 1876, to 63,236 in 1880; from Asiatic Turkey, they have risen from 93,965 in 1876, to 185,543 in 1880; from Brazil, 41,604 in 1876, 2623 in 1877, 5730 in 1880, and none in the intermediate years; from the Argentine Republic, 3,539,589 in 1876, 898,155 in 1879, 1,248,553 in 1880; from the Cape, 1,496,039 in 1877, 1,819,772 in 1880; from India, 3,927,934 in 1876, 2,911,974 in 1880; from Victoria, 1,667,330 in 1876, 1,158,686 in 1880; from New S. Wales, 83,167 in 1878, 36,995 in 1880; New Zealand, 168,984 in 1878, 334,792 in 1880. The approximate London market values of sheep-skins are:—Cape, 10–34*s.* a doz.; fine wool, 28–59*s.*; superior, 40–82*s.*; Mogador, 14–27*s.*; Buenos Ayres, 4–13*d.* a lb.; Australian, 4–16*d.*; tanned E. Indian, best, 2–4*s.*; ordinary to good, 1*s.*–2*s.* 9*d.*

Walrus.—Our imports of walrus skins from Christiania in 1879 were valued at 7900 *kroner* (of 13½*d.*).

Commerce in Hides (unenumerated, but chiefly Ox and Cow).—Our imports of undressed dry hides in 1880 were from:—Bengal and Burma, 411,874 cwt., 1,473,720*l.*; Straits, 48,175 cwt., 110,114*l.*; Bombay and Sind, 47,546 cwt., 130,094*l.*; British S. Africa, 34,133 cwt., 128,182*l.*; Holland, 21,447 cwt., 66,692*l.*; Brazil, 13,500 cwt., 48,233*l.*; Germany, 11,764 cwt., 55,860*l.*; Belgium, 7697 cwt., 24,532*l.*; Russia, 5938 cwt., 40,977*l.*; Argentine Republic, 4355 cwt., 14,851*l.*; France, 3371 cwt.; 11,452*l.*; Madras, 2601 cwt., 7512*l.*; other countries, 47,071 cwt., 159,236*l.*; total, 659,472 cwt., 2,271,455*l.*

Undressed wet hides, from:—Uruguay, 104,495 cwt., 338,830*l.*; Brazil, 101,637 cwt., 301,892*l.*; Australia, 101,371 cwt., 222,903*l.*; Belgium, 60,426 cwt., 177,356*l.*; France, 53,934 cwt., 143,667*l.*; Germany, 32,619 cwt., 77,220*l.*; Holland, 32,121 cwt., 82,887*l.*; Argentine Republic, 30,550 cwt., 83,601*l.*; British S. Africa, 19,217 cwt., 51,547*l.*; Portugal, 10,502 cwt., 33,229*l.*; New Granada, 5240 cwt., 19,475*l.*; Sweden, 4897 cwt., 14,162*l.*; Denmark, 3657 cwt., 10,032*l.*; other countries, 21,650 cwt., 51,326*l.*; total, 582,316 cwt., 1,608,127*l.*

Tanned hides, from:—United States, 19,923,807 lb., 984,075*l.*; Australia, 7,595,257 lb., 318,727*l.*; Madras, 4,995,439 lb., 229,799*l.*; Straits, 2,778,159 lb., 100,195*l.*; British N. America, 838,366 lb., 38,835*l.*; Bombay and Sind, 738,471 lb., 38,258*l.*; Bengal and Burma, 444,220 lb., 21,024*l.*; France, 437,415 lb., 39,393*l.*; Holland, 418,873 lb., 36,811*l.*; Belgium, 337,579 lb., 24,526*l.*; China, 239,819 lb., 11,681*l.*; other countries, 311,024 lb., 16,758*l.*; total, 39,058,429 lb., 1,860,082*l.*

Tanned and curried hides, from:—France, 3,850,457 lb., 513,164*l.*; United States, 2,321,385 lb., 165,877*l.*; Germany, 1,181,845 lb., 306,133*l.*; Holland, 329,166 lb., 58,897*l.*; other countries, 256,123 lb., 29,412*l.*; total, 7,938,976 lb., 1,073,483*l.*

Varnished, japanned, or enamelled hides, from:—United States, 297,841 lb., 44,631*l.*; Holland, 148,695 lb., 40,898*l.*; Germany, 55,958 lb., 12,623*l.*; other countries, 153,543 lb., 23,306*l.*; total, 656,037 lb., 121,458*l.*

Our exports of hides in 1880 were:—Dry: 179,917 cwt., 630,955*l.*, to Germany; 59,636 cwt., 224,851*l.*, Holland; 44,000 cwt., 160,960*l.*, United States; 17,091 cwt., 56,505*l.*, Russia; 16,898 cwt., 63,307*l.*, Italy; 6000 cwt., 23,218*l.*, Belgium; 5433 cwt., 20,250*l.*, Sweden; 13,854 cwt., 52,038*l.*, other countries; total, 342,829 cwt., 1,232,084*l.* Raw: 44,673 cwt., 91,383*l.*, United States; 36,772 cwt., 58,282*l.*, Germany; 10,943 cwt., 18,113*l.*, Holland; 3129 cwt., 7031*l.*, Canada; 3017 cwt., 5448*l.*, Belgium; 2262 cwt., 4454*l.*, France; 4465 cwt., 9725*l.*, other countries; total, 105,261 cwt., 194,436*l.*

Our imports of hides from the undermentioned countries have fluctuated as shown:—

Abyssinia.—Undressed, 7289 cwt. in 1876, 327 in 1878, 2159 in 1879, and 324 in 1880.

Aden.—Undressed, 8190 cwt. in 1876, 113 in 1879, 8294 in 1880.

Algiers.—Raw, 2,051,701 *kilo.* (of 2·2 lb.) in 1879.

Argentine Republic.—Undressed, 94,479 cwt. in 1877, 32,961 in 1879, 34,905 in 1880.

Austro-Hungary.—Vienna, 24,672 metrical *centners* in 1878, 48,950 in 1879; Fiume, raw, 1400 *kilo.* in 1879.

Bahamas.—167*l.* worth in 1879.

Barbados.—363*l.* worth in 1877, 913*l.* in 1878.

Belgium.—Undressed, 51,069 cwt. in 1877, 82,021 in 1878, 68,123 in 1880. Dressed, 176,635 lb. in 1878, 418,906 in 1880.

Brazil.—Undressed, 137,351 cwt. in 1878, 115,137 in 1880. Pernambuco in 1878–9 exported, dried, 31,717 *kilo.* to Great Britain, 28,077 France, 25,606 Portugal, total value 3002*l.*; salted, 383,691 *kilo.* Great Britain, 937,976 United States, 585,868 France, 40,770 Spain, 463,269 Portugal, total value 75,523*l.*; in 1880, 61 tons, 2267*l.* Maceio exported in 1877, 4728 pieces (average 28 lb. each) to Great Britain, 1440 New York and Lisbon; in 1879, 36,775; in 1880, 11,405. Bahia exported 1,432,864 *kilo.* in 1877–8, and 1,773,965 in 1878–9, principally to the United States and Germany. Santos exported 397,000 *kilo.* in 1879. Ceara exported in 1878, 372,808 *kilo.* to England, 31,966 Havre, 775,863 Hamburg, 7800 New York.

British India.—Undressed, 281,198 cwt. in 1876, 463,764 in 1880; dressed, 14,835,979 lb. in 1878, 6,178,370 in 1880.

Bulgaria.—Rustchuk, in 1879, exported 254,196 *kilo.* (250 tons) to Austria.

Canada.—Dressed, 939,759 lb. in 1876, 372,359 in 1879, 1,066,043 in 1880.

Cape.—Undressed, 15,370 cwt. in 1876, 44,503 in 1878, 29,442 in 1880.

Central America.—Undressed, 72 cwt. in 1876, 1113 in 1878, 356 in 1880.

Chili.—Undressed, 318 cwt. in 1876, 17,042 in 1879, 1566 in 1880; dressed, 33,026 lb. in 1876, 3929 in 1877, 199,965 in 1878, 224 in 1879, 2930 in 1880.

China.—Undressed, 5671 cwt. in 1876, 60,871 in 1878, 2705 in 1880. Hankow exported in 1879, 7797 pieces, 1656*l.*; Kiungchow, 490 *piculs* (of 133⅓ lb.), 818*l.*; Newchwang, 17,665 pieces; Tientsin, 4354 *piculs*; Canton, in 1878, 653 pieces of skins, 873¾ *piculs* of hides.

Costa Rica.—San José exported 308,794 lb. in 1879.

Denmark.—Undressed, 20,806 cwt. in 1877, 5632 in 1880; Copenhagen exported 1,166,172 lb. to Great Britain in 1878.

Ecuador.—Undressed, 680 cwt. in 1876, 18 in 1877, 115 in 1879, 89 in 1880. Guayaquil exported in 1878, 5711 *quintals* raw, 17,133*l.*, to the United States, and 12,504 halves tanned, 8752*l.*, to S. America; and in 1880, 8859 *quintals* raw, 22,148*l.*, and 4861 tanned, 2916*l.* Manabi, in 1878, exported 1321 *quintals*, 3963*l.*

Egypt.—Undressed, 1250 cwt. in 1877, 718 in 1878, 1286 in 1880. In 1879, the values were 620*l.* to Austria, 380*l.* France, 1950*l.* Great Britain, 45,500*l.* Greece, 280*l.* Italy, 62,500*l.* Turkey.

Falklands.—Undressed, 4315 cwt. in 1878, 2679 in 1880. The value of the exports was 5020*l.* in 1879.

France.—Undressed, 26,866 cwt. in 1876, 57,305 in 1880; dressed, 2,727,190 lb. in 1876, 4,338,485 in 1880. Calais in 1878 sent 2188 *kilo.* prepared to Great Britain, and 76,811 *kilo.* in 1879.

French E. Indies.—Dressed, 24,600 lb. in 1876, 12,713 in 1877, none since.

Gambia.—Exported 15,380 pieces in 1878.

Germany.—Undressed, 45,002 cwt. in 1876, 21,143 in 1878, 44,383 in 1880; dressed, 1,269,143 lb. in 1876, 954,578 in 1878, 1,318,659 in 1880. Hamburg sent to Great Britain, 33,458 cwt. dry and salted in 1877, 13,972 in 1879. Königsberg exported 1535 cwt. raw in 1878, 424 in 1879.

Greece.—Dressed: Syra in 1877 sent 60,247*l.* worth to Turkey, 23,259*l.* to the Danubian Principalities, 2748*l.* to Austria; in 1879, 492*l.* Turkey, 251*l.* Austria, 200*l.* Russia.

Guatemala.—Exports in 1877, 62,343 *dol.* worth; in 1878, 844½ *quintals* to England, 1293 France, 2176 Germany, 822 New York, 149 California; 1879, 412,605 Germany, 12,360 New York.

Hawaiian Islands.—Exports 1880, 24,885 pieces.

Holland.—Undressed, 55,705 cwt. in 1876, 53,568 in 1880; dressed, 941,372 lb. in 1876, 896,734 in 1880.

Java.—Exports 1878–9, 357,353 pieces and 1240 *piculs* to Holland, 7212 pieces to the Channel for orders, 1200 pieces to France, 7369 pieces to Italy, 5695 pieces and 872 *piculs* to Singapore.

Madagascar.—Undressed, 252 cwt. in 1877, 3088 in 1879, none since.

Mauritius.—Undressed, 5341 cwt. in 1876, 2945 in 1880.

Morocco.—Undressed, 0 in 1877, 5445 cwt. in 1878, 1014 in 1880. Tangiers exported in 1879, 2727 cwt., 6000*l.*, to Great Britain; 1818 cwt., 4365*l.*, France; 21 cwt., 42*l.*, Spain. Mogador, in 1880, sent 44 bales, 150*l.*, to Great Britain; 667, 2250*l.*, France; 243, 770*l.*, Portugal.

Natal.—Undressed, 32,555 cwt. in 1876, 17,496 in 1878, 23,908 in 1880.

New Granada.—Undressed, 12,217 cwt. in 1878, 574 in 1879, 6059 in 1880.

New S. Wales.—Undressed, 9386 cwt. in 1878, 79,972 in 1880; dressed, 2,257,041 lb. in 1877, 1,694,015 in 1880.

New Zealand.—Undressed, 39 cwt. in 1878, 6335 in 1880; dressed, 140,448 lb. in 1878, 446,102 in 1880.

Persia.—Bushire exported in 1879, 4000 *rupees'* worth to England, 5000 *r.* India; Lingah, 2800 *r.* India, 1950 *r.* Persian coast; Bahrein, 6000 *r.* Koweit, Bussora, and Bagdad.

Peru.—Undressed, 2859 cwt. in 1876, 622 in 1878, 1235 in 1880. Mollendo exported 538 *quintals* in 1878, and 1307 *q.* dry in 1879.

Philippines.—Undressed, 1024 cwt. in 1876, 102 in 1880. Manilla, in 1879, exported 7976 *piculs*, 12,761*l.*, to China and Japan.

Portugal.—Undressed, 17,456 cwt. in 1877, 10,983 in 1880.

Queensland.—Undressed, 1315 cwt. in 1879, 5019 in 1880.

Roumania.—Galatz exported 341 bales in 1879.

Russia.—Undressed, 482 cwt. in 1876, 6020 in 1880; dressed, 88,225 lb. in 1876, 46,694 in 1880. Riga shipped 14,839 *poods* (of 36 lb.) in 1877, 11,311 in 1879. Poti, in 1877–8, sent away 5654 *poods*, and 2149 from Persia.

Saigon.—Exports in 1879, 10,582 *piculs.*

San Domingo.—Exports in 1878, 630 pieces to Great Britain, 490 France, 3100 Italy, 3980 Spain, 460 United States, 560 W. Indies; in 1880, 1340 Italy, 2541 Spain, 7142 United States, 97 W. Indies.

S. Australia.—Dressed, 38,108 lb. in 1878, 303,143 in 1880.

Spanish W. Indies.—Puerto Rico exported in 1878, 167 *quintals* United States, 5673 Spain, 637 Germany.

Straits Settlements.—Undressed, 28,444 cwt. in 1876, 48,213 in 1880; dressed, 603,389 lb. in 1876, 2,778,159 in 1880.

Surinam.—Exports in 1878, 9221 *kilo.*

Sweden and Norway.—Christiania exported 95,200 *kroner* worth in 1875, 4200 *kr.* in 1878. Gothenburg exported 10,960 cwt. in 1879.

Tasmania.—Dressed, 65,803 lb. in 1878, 38,141 in 1880.

Tripoli.—Bengazi, in 1878, sent 50,000 pieces, 4000*l.*, to Malta. The value of the exports was 2000*l.* in 1879, and 4500*l.* in 1880.

Turkey.—Aleppo exported in 1878, 181 tons, 10,824*l.*, to France; 5, 320*l.*, Italy; 11, 704*l.*, Austria; 52, 3328*l.*, Turkey; 12, 768*l.*, Egypt. Thessaly exported 15,000*l.* worth in 1880. Samos sent 19,300*l.* worth tanned to Turkey and Egypt in 1879. Van exported 1500*l.* worth in 1879. Kerasund shipped by steamer in 1879, 557 bales, 3899*l.* Trebizond in 1879 sent 940 bales (of 12 and 60 pieces), 6580*l.*, to Turkey; 1567, 10,969*l.*, France; 501, 3507*l.*, Russia; 80, 560*l.*, Greece. Dedeagatch, in 1879, exported 1300 bales, 40,000*l.* Alexandretta, in 1879, sent 280 tons, 16,800*l.*, to France; 3, 180*l.*, Austria; 10, 600*l.*, Russia; 96, 6720*l.*, Turkey; 29, 2030*l.*, Egypt. Adana, in 1879, sent 250 tons, 7500*l.*, to France; 140, 4200*l*, Turkey; 27, 810*l.*, Greece. Jaffa exported 18,000 *okes* (49,500 lb.), 666*l.*, for Turkey in 1879.

United States.—Undressed, 115,767 cwt. in 1876, 7888 in 1879; 14,358 in 1880; dressed, 16,716,711 lb. in 1879, 22,543,033 in 1880. Savannah exported 8758 bundles in 1880. Galveston exported in 1879–80, 9878 bales and 7510 single, dry; and 6905 bundles wet-salted. Texas State in 1878–9 exported 28,104,065 lb., 562,081*l.*

Uruguay.—Undressed, 116,738 cwt. in 1876, 65,846 in 1879, 104,691 in 1880.

Venezuela.—Puerto Cabello exported in 1879, 10,126 *kilo.* to Great Britain, 88,717 Germany, 75,794 United States, 5756 France, 696 Holland, 1023 Spain. Ciudad Bolivar sent 35,562 pieces, 762,234 lb., to New York in 1879.

Victoria.—Undressed, 0 in 1878, 2710 in 1879, 8705 in 1880; dressed, 3,506,562 lb. in 1876, 5,096,696 in 1880. The values of the exports in 1878 were 9417*l.* hides, and 19,706*l.* skins and pelts.

(See Feathers, Fur, Hair, Leather.)

SMALLWARES (Fr., *Tissures*; Ger., *Klein-*, *Spiel-*, or *Nürnberger waaren*).

Mechanical inventions during the past century have revolutionized the aspect of society in nearly every one of its phases. Amongst the most important class of changes that has resulted, is the subdivision and rearrangement of labour for the production of articles of merchandize. The facilities which the manufacturer has acquired for infinitely varying his productions and increasing the quantity, has done much to necessitate a reorganization of the means of distribution. The consequence is that terms formerly distinctive of certain occupations are falling into disuse, or changing their signification. Illustrations of this fact may be found in connection with the trades dealing in materials for apparel. A "draper" formerly meant specifically a dealer in woollen cloth; subsequently it became generic, and an adjective was required, such as linen or woollen, to clearly define its meaning. More recently it has quite lost its original signification, the person whom it formerly indicated having become a "clothier." "Haberdashery" was the term in use some time back for the branch of trade dealing more particularly with fabrics destined for feminine wear, and the numerous small etceteras pertaining thereto. This term has been almost abandoned in favour of "draper," the one cast aside by the modern "clothier." In place of the haberdasher, there has sprung up another distinctive business character, the "smallware dealer," who has taken a portion of the haberdasher's specialities, and combined therewith many other articles having a general likeness, or similar origin. Out of this amalgamation of old and new, the modern smallware business has sprung. Under the term "smallwares" are comprehended a great variety of articles, comparatively insignificant in themselves, but important as accessories necessary to complete and perfect the use of other things.

Only a rough classification of smallwares can be attempted, as whatever principles be adopted, those of one division will frequently be found in another with only slight specific variations. Smallwares, as ordinarily understood, are mainly allied to textiles, in the materials of which they are composed, the manner of their fabrication, and their ultimate uses. They may be divided into three great classes: (1) for purposes of attire, (2) for upholstery uses, and (3) in which may be grouped the numerous articles ordinarily denominated fancy goods.

The first named division is probably the most extensive. In this, "braids" form a considerable class of themselves, as they are produced in all materials, gold, silver, silk, wool, worsted, alpaca, mohair, and cotton. Most of these are made in various widths (¼–2 in.), and in numerous shades of every colour, according to the requirements of popular taste. Manchester, Derby, Leicester, and Nottingham are the chief centres of manufacture in England, whilst great quantities are produced also in France and Germany. The texture of plain braids is usually alike on both sides. The best qualities are generally made up in ¼-gross cards or knots, four of which are put in a box; the commoner are made up in ¼-gross pieces, four pieces in a package. These lengths ought to be full, but too often they range from $\frac{1}{36}$ to $\frac{1}{12}$ short of the nominal length. The blame for this is frequently, and nearly always unjustly, placed upon the manufacturer, who, however, could rarely, without incurring detection, deliver short-length goods to his contracts. The custom is to quote for proper or full lengths, when the buyer gives instructions for them to be made $\frac{1}{36}$, $\frac{1}{18}$, or $\frac{1}{12}$ less, a corresponding deduction being made from the full-length quotation prices. This is one of the vicious results of excessive and unscrupulous competition, and is a custom against which the retailer should be carefully on his guard, as it is on him that the loss falls when undetected. "Bindings" are a kindred article to braids, but usually of a rather different texture; the two sides are not alike, the front having a diagonal or "herring-bone" twill, whilst the back is plain. "Ferreting" is an old name for a silk flannel-binding of the latter texture. These are not in such extensive use at present as formerly. "Cords" are composed of the same materials as braids, and, as their name indicates, are round instead of flat. They are generally black, though sometimes made in colours; and may be had either with or without cores. They are made up in a similar manner to braids, in gross packages. In connection with these may be mentioned elastic cords and braids, which, instead of having an inelastic fibrous core, have substituted therefor fine strips of indiarubber, around which the covering is plaited as in those containing a core. These strips vary in number and thickness as may be required, from a single one in cords to whatever number may be demanded by the width of braids. They are mostly black, but small quantities are also produced in colours. They are generally carded in lengths varying from ¼ to a full gross, or even more, according to width and thickness. Leicester, Derby, and Manchester are the places of manufacture. The remarks concerning lengths made in connection with braids apply also in this case. Sometimes, for trimming purposes, braids are made in variegated colours, and in wave and vandyked or other fancy forms; but these changes are not frequent, and do not prevail long at a time.

"Trimmings" constitute a large proportion of the smallwares of dress, and include "gymps," "fringes," "ornaments," "tassels," and fancy buttons, covered and plain. The first are usually made from the cords already referred to. These are wrought up into numerous tasteful forms, and sometimes ornamented with beads. The widths vary from very narrow to several inches wide. They are made up on cards of various lengths. "Ornaments" are a kindred trimming, consisting of single objects or sets; they vary greatly in price, according to the quantity of work in them and the value of material. They are made by the same manufacturers as gymps. In England, these are chiefly found in London, Coventry, and Nottingham, but great quantities are imported from France and Germany, when fashion is in their favour. "Fringes" are of various materials, widths, forms, and colours, plain, knotted, and otherwise ornamented. These are usually carded like gymps, in varying lengths. Coventry, Leicester, Nottingham, Derby, Macclesfield, and other places in this country produce them when in demand, along with several districts on the Continent. "Trimming-buttons," when covered with silk or other materials, are generally made by the manufacturers of gymps and ornaments. Plain, that is uncovered, buttons, in ivory, bone, glass, metal, vegetable ivory, or composition, are put up on cards and boxed; Birmingham is a great seat of manufacture, and has numerous competitors in several centres in France and Germany (see Buttons, pp. 557–571).

Yarns in silk, wool, worsted, merino, and cotton, form a considerable division of smallwares. They include knitting, mending, netting, crochet, and a large number of fancy yarns. The first-named material, being costly, is not in extensive use compared with the others. Wool yarns are produced in great variety, from common coarse knittings to fine Saxony and Berlin wools of a very superior quality, which are fabricated into articles of comparative luxury. An almost endless variety of colours, shades, mixtures, and variegated yarns are produced to meet public demand. Worsted, save for knitting purposes, is not in much request. "Mendings" are adjuncts of the hosiery trade, and their character depends upon what is in vogue for the fabrication of the medium and lower classes of hosiery. As a rule, there is always a considerable production in worsted, wool, and merino, and occasionally in cotton yarns, for the smallware section of the trade. Leicester, Wakefield, Halifax, Bradford, and other places of less note in the different woollen manufacturing districts, are the chief centres of production. A fair quantity is also imported from the Continent, chiefly from Germany; but this is likely to diminish, owing to the superiority of the home productions, from the improved methods of dyeing and finishing that have of late been adopted.

"Sewings" are chiefly composed of silk, including "patent silk," cotton, and linen threads. These embrace every variety of colour, and count or degree of fineness, to suit the multifarious purposes in which they are consumed. Silk thread was formerly more extensively used, relatively considered, than at present. It was then composed of net silk, and was mostly sold in small skeins by weight, colours commanding a higher price than blacks and whites. Derby, Leek, Congleton, Macclesfield, and Coventry, had almost a monopoly of its production at that time. During the past 15 years, however, it has to a great extent been superseded in public favour by the greater cheapness and excellence of "patent silk" sewings, produced from silk waste (see p. 1755). The article obtained from the latter is more uniform in thickness, and better adapted for use in the sewing-machine now so extensively employed. Bradford, Leicester, and Derby, are the chief places of production, though several isolated mills are to be found in other parts of the country. The production of sewing-cottons has become a large and very important branch of trade, and the high degree of excellence to which it has been carried in this country has secured for our manufacturers a practical monopoly of the trade. The yarns from which these threads are made are chiefly spun in Bolton and Manchester, from the best classes of cotton, and which are nearly always combed, not carded, thereby securing an equality in the length of fibre, which yields a thoroughly level and uniformly strong yarn, highly essential for the production of good sewing-cottons. The machinery from which they are produced is mainly that of the series used in the manufacture of twines (see Rope, pp. 1595–1610), modified in size; the operations are nearly identical, consisting in doubling, twisting, cabling, gasing, and polishing. The last process of filling the reels is effected in a very ingenious machine, which automatically performs all operations necessary for supplying, filling, measuring, and discharging the reels ready for packing. Various qualities are produced, depending chiefly upon the class of cotton from which the single yarn is made; they are generally three-, six- or nine-fold, the lowest fold being the commonest quality, and rising in proportion. The numbers run from 4's to 200's, which latter is almost as fine as human hair. The lengths upon the reels vary from 200 to 1000 yd., or even more; as a rule, medium lengths are found the most useful, the small reels requiring to be replaced too often when used in the sewing-machine, the large ones being too heavy for the proper tension necessary for good work. The reels are made up in packages of one dozen each, and sold by the gross. The chief centres of production are Paisley, Manchester, Bolton, Leicester, and a few other places. In the first-named district there are some very large firms, who have also branch establishments in the United States. The produce of the English establishments is exported to all parts of the world, in spite of, in some cases, almost prohibitory tariffs. Linen threads are now but little used in the production or manufacture of articles of clothing, but retain their place for upholstery, cordwainers', and saddlery uses, where great strength is required. Formerly this thread was made up for consumption in small skeins, and sold by weight; but it is now chiefly put on reels, each reel containing a given weight of thread by which it is sold, the length varying with the count or degree of fineness. Belfast and district produces the greatest portion of linen thread, though some is manufactured in Glasgow, in several towns in Yorkshire, and in a few other places.

As adjuncts to the articles above described, and always found in connection with them, must be mentioned needles for plain and machine sewing; thimbles, pins, hooks, shuttles, &c., for knitting, netting, crochet, tatting, and other fancy-work purposes; hair-pins, combs of every variety, metallic ornaments, and an endless catalogue of trifles, changing their appearance, but not their use, every season. These articles are produced in metal, ivory, bone, and wood, and in a variety of fancy forms. Redditch maintains its pre-eminence as the centre of production for needles of all descriptions, whilst Birmingham manufactures nearly all the rest of the articles named.

Another class of goods that, though kindred, properly speaking form a distinct branch, but are often found in connection with the preceding, are upholsterer's smallwares, which include fringes in silk, worsted, and cotton, for cornices, hangings, and curtains; plain, knotted, balled, and otherwise ornamented. These are made in various widths, according to intended use or requirement. Curtain-borderings, gymps, cords, bell-ropes, bands, loops, laces, bindings, chair- and ladder-webs, blind-lines and tassels, ottoman- and pillow-tassels, chair-gymps, plain and waved: these are made in silk, worsted, cotton, and jute. Appertaining to them are ornamental buttons, plain, covered, and gilt, fancy-gilt nails, rings, hooks, pins, &c. The trimmings are chiefly made in London, Manchester, Leicester, and Coventry; and the metallic articles in Birmingham.

The fancy department of a smallware establishment is made to include a large assortment of articles in many respects quite incongruous, but which are usually thus grouped because of their small importance and limited demand not warranting any other arrangement. These include perfumes (see pp. 1523–32), fancy soaps (see Soap), pomades, hair-, tooth-, and nail-brushes, and other toilet requisites. Small bags, satchels, glove-boxes, handkerchief-cases, purses, jewel-cases, trinket-boxes, jet and vulcanite ware, and the innumerable small things denominated *articles de Paris*, coming from that city and other Continental centres of production of fancy wares. To these have latterly been added kindred classes of articles coming from Eastern countries, India, China, and Japan.

It will be obvious that the foregoing is only an inadequate representation of the numberless trifling adjuncts to our necessaries or luxuries, which the growing wealth and refinement of the age have called, and are still calling into existence, and which, for want of more clear and definite means of classification, are being grouped under or attached to a division of trade that has hitherto been clearly defined and widely known as the "smallware trade." To make a complete enumeration of the additions that have occurred would require a volume. The principle of change of which these articles are the outcome is still active, and its operations in the future will continuously lead up to new developments in the products of industry, new groupings of the objects of merchandize, and new methods of conducting business. R. M.

SOAP, RAILWAY-GREASE, AND GLYCERINE.

Soap (Fr., *Savon*; Ger., *Seife*).—Although soap has been made and used for many centuries (it is mentioned by Pliny, and the remains of a soap-factory, with lime, &c., remaining in it, are still shown in Pompeii), the principles which should guide its manufacture have only been discovered in quite recent times. A proper comprehension of these principles is indispensable to every one who would become a successful manufacturer, because soap-making is essentially a chemical operation; but as they can only be dealt with very briefly here, the reader unacquainted with them is recommended to consult any modern elementary work on chemistry.

Although, in ordinary parlance, the term "soap" denotes simply that combination of fatty matter with alkali which, by its detergent properties, aids in the removal of grease and dirt in washing (in which sense alone will it be used in this article), it is highly important to remember that "soaps" as a class are, strictly speaking, "salts," using that term in the chemical sense. Every salt contains an acid and a base, having opposite properties, and producing by their union a third substance differing from either. Thus Glauber's salts, sulphate of soda, or sodium sulphate (all are synonymous terms), is a compound of sulphuric acid and soda, or

Salt = *acid* + *base.*
Sulphate of soda = sulphuric acid + soda.

All the neutral fats of commerce which are used in soap-making, such as tallow, palm-oil, coconut-oil, cotton-seed-oil, and greases of various kinds, are also, from a chemical point of view, "salts" of which the "base" is (not soda but) glycerine, and the "acid" (not sulphuric but) a mixture of various "fatty acids," which by proper means, may, if desired, be separated from each other, and prepared in a state of greater or less purity. Hence,—

Salt = *acid* + *base.*
Neutral fat (e. g. tallow) = various fatty acids + glycerine.

Theoretically, soap-making is nothing more than turning out the glycerine base by a strong mineral base, or alkali, such as potash or soda. Hence,—

Neutral fat + Alkali = { Fatty acids + Alkali, or "Soap" } + Glycerine.

As, however, certain oils much used by the soap-maker are already fatty acids, and contain no glycerine (e. g. oleic acid, sometimes erroneously called oleine, a bye-product of the candle-factory), the formation of soap from them is simply a direct combination of fatty acids with the proper proportion of alkali. This process will be dealt with in describing special soaps.

While, therefore, chemically speaking, any combination of fatty acids with a mineral base is a "soap," in practice no soaps are made except with potash or soda, as only those soaps are soluble in water; all others, such as those formed by the union of fatty acids with lime, baryta, or even with the oxides of the metals, as lead, copper, &c., are insoluble in water, though some of them are used in pharmacy: a "plaster," for instance, is usually a soap from the fatty acids of soft oils, with oxide of lead as a base, and chemically speaking, is an oleate of lead.

A further acquaintance with the theory of salts will make it clear that, in the case of mineral acids and bases there is a certain definite proportion peculiar to each, in which (or in a simple multiple of which) they combine with each other. Thus 31 parts of pure caustic soda (100 per cent.) require 49 parts of oil of vitriol (100 per cent. sulphuric acid) to form the neutral salt, sulphate of soda, and in the operation, 9 parts of water are formed, the hydrogen of which is derived from the acid, and the oxygen from the base. The combined weight of the products is of course exactly equal to the sum of the weight of the constituents, or,—

31 parts soda + 49 parts sulphuric acid = 71 parts sulphate of soda + 9 parts water.

This number, called the "combining proportion" or "equivalent" of each substance, is determined by chemical research. It can scarcely be too strongly insisted on that the fatty acids have their equivalents also; thus the determination of the quantity of soda necessary for their saponification is a matter of calculation, and hence the varying equivalents of the different fatty acids is the real explanation of the well-known fact that the "yield" of soap is so different from various fats.

To revert for a moment to the combination of sulphuric acid and soda,—considerable heat is evolved in the process, which has its parallel in saponification; further, if either constituent had been in excess, there would have resulted a mixture of neutral sulphate of soda with the remainder of whichever constituent was in excess. If, however, twice 49, or 98, parts of sulphuric acid had been taken, an acid sulphate, or bisulphate, of soda, would have been formed. The fatty acids are remarkable in this respect, that their combining proportions or equivalents are much higher than those of mineral acids. Thus to combine with 31 parts of soda (100 per cent.), 284 parts of stearic acid are required, 282 parts of oleic acid, 256 parts of palmitic acid, and only 200 parts of lauric acid, one of the chief fatty acids of coco-nut-oil. Hence, while tallow gives the least "yield" of soap, among the fats usually employed, coco-nut-oil gives the most, and palm-oil occupies an intermediate position.

What has been said above with regard to 31 parts of soda, applies with equal force to potash, replacing 31 by 47, which is the combining proportion of potash.

From the explanation now given, it is easy to calculate the quantity of soda or potash necessary to completely saponify,—

100 lb. of	Soda, 100 per cent.	Potash, 100 per cent.
Tallow	10·50 lb.	15·92 lb.
Palm-oil	11·00 „	16·67 „
Coco-nut-oil	12·44 „	18·86 „
Oleic acid	10·52 „	15·95 „

It is obvious that the proportion of alkaline ley to be used must be regulated by its strength; thus, if ley containing 20·0 per cent. soda be used, i. e. $\frac{1}{5}$ its weight of soda at 100 per cent., five times the given weights must be used for 100 lb. fatty material.

It will be convenient here to explain briefly the causes of the differences in combining proportion among the various fats. Their fatty acids are all composed of the three elements, carbon, hydrogen, and oxygen, combined in different proportions of the two first-named, but all containing the same quantity of oxygen. They may be arranged in a series, known as the "adipic," of which the lowest term, formic acid, contains 12 parts by weight of carbon, 2 parts hydrogen, and 32 parts oxygen. The other terms of the series differ from each other by 12 parts carbon and 2 parts hydrogen. The following table gives some of the principal terms of this series, $C_nH_{2n}O_2$, from which, it is clear that the differences in their equivalents are due to the differences in the quantities of carbon and hydrogen entering into their composition, which also affect their melting- and boiling-points.

TABLE A.—THE CHIEF FATTY ACIDS OF THE SERIES $C_nH_{2n}O_2$ OCCURRING IN NATURAL FATS. (Some intervening terms omitted.)

Name.	Formula.	Equivalent.	Fusing-point C.	Boiling-point C.	Natural Fat.
Formic acid	CH_2O_2	46	−6°·0	105°.3	
Acetic „	$C_2H_4O_2$	60	17·0	117	
Butyric „	$C_4H_8O_2$	88		164	Butter.
Caproic „	$C_6H_{12}O_2$	116	−9·0	200	Volatile acids of coco-nut-oil, &c.
Oenanthylic acid	$C_7H_{14}O_2$	130		212	
Caprylic „	$C_8H_{16}O_2$	144	15·0	236	
Pelargonic „	$C_9H_{18}O_2$	158		260	
Capric or Rutic acid ..	$C_{10}H_{20}O_2$	172	30·0	..	
Cocinic acid	$C_{11}H_{22}O_2$	186	35·0	..	Fixed acids of coco-nut-oil, &c.
Lauric „	$C_{12}H_{24}O_2$	200	43·0	..	
.. ..	$C_{13}H_{26}O_2$	214	47·0	..	
Myristic „	$C_{14}H_{28}O_2$	228	53·8	..	
.. ..	$C_{15}H_{30}O_2$	242	56·0	..	
Palmitic acid	$C_{16}H_{32}O_2$	256	62·5	..	Palm-oil.
Margaric „	$C_{17}H_{34}O_2$	270	66·0		
Stearic „	$C_{18}H_{36}O_2$	284	69·2	..	Tallow.
Cerotic „	$C_{27}H_{54}O_2$	410	79·0	..	Bees'-wax.
Melissic „	$C_{30}H_{60}O_2$	452	89·0	..	

The fatty acid of the fluid constituent of most natural fats and oils, called oleic acid, belongs to another series, $C_nH_{2n-2}O_2$, known as the "acrylic;" its formula is $C_{18}H_{34}O_2$, and its equivalent is 282.

For reasons which are not within the scope of the present article, the true chemical equivalent of these fatty acids is always taken at thrice the above numbers. The acids can all form salts containing once, twice, or thrice 31 parts of soda, and it requires *three* of the above equivalents of any acid to form a neutral fat with *one* equivalent of glycerine, so that the process of the saponification of a neutral fat by caustic soda may be thus represented,—

(3 equivalents, stearic acid and soda.)

$$\underset{\text{Tristearine.}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Caustic soda.}}{3NaHO} = \underset{\substack{\text{Sodium stearate}\\ \text{or soap.}}}{3(C_{18}H_{35}O_2Na)} + \underset{\text{Glycerine.}}{C_3H_5(OH)_3}$$

(1 equivalent, glycerine.)

$$890 + 120 = 918 + 92$$

Consult also Candles, pp. 579–80. Glycerine will be treated of separately at the end of this article (pp. 1798–1802).

Raw Materials.—The raw materials employed in the production of pure soaps are (1) fatty matters of various kinds, (2) rosin, or colophony, (3) solution of caustic soda or potash. In the article Oils and Fatty Substances, will be found full descriptions of the different kinds of fats and oils suitable for soap-making; on pp. 1458–62, are directions for refining and bleaching them, preparatory to their saponification; and on pp. 1462–77, are instructions for their analysis, the detection of adulterants, &c. Rosin will be discussed under Resinous and Gummy Substances (see also Wax), and Alkali contains a full account of the manufacture of soda and potash. But very few general remarks, therefore, are necessary in treating of raw materials, and these will be especially practical in their character.

Since the selection of the raw material depends entirely upon the kind of soap which it is desired to produce, it may be remarked at the outset, that soaps are divided into two classes, "hard" and "soft." For the production of what is technically called "soft soap," it is necessary to use potash as an alkali, to the almost entire exclusion of soda. Potash soaps are deliquescent, and do not dry up when exposed in solution to the air, but retain water enough to form a soft slimy jelly. Soda soaps neither retain so much water, nor absorb it from the air, but harden when exposed, partly from loss of water. This difference is best seen in the case of the salts of pure fatty acids thus:—

100 parts dry potassium oleate absorb 162 parts water from the air.
100 ,, ,, palmitate ,, 35 ,, ,,
100 ,, sodium stearate ,, 7½ ,, ,,

In the manufacture of soft soap, oils that are fluid or semifluid at the ordinary air-temperature are usually employed, and especially linseed- and other seed-oils, and the cheaper varieties of fish-oils. Certain oils make a hard or a soft soap, according as the alkali employed is soda or potash, or, in some cases, a mixture of both. As a general rule, not more than ¼ of the potash in a soft soap can be replaced by soda (for cheapness sake) without impairing the quality of the soap.

Hard soaps invariably contain soda as their base, and, *ceteris paribus*, the hardness varies inversely as the quantity of water in the soap. An oil as fluid as commercial oleic acid will produce a hard soap with soda, if the process be so conducted that but little water is present during the operation. Tallow, mixed with varying proportions of rosin, is employed for household "yellow" soap; kitchen-grease, bone-fat, discoloured lard, and other greases, with rosin, for inferior grades of the same; while the same greases, and palm-, cotton-seed-, olive-, coco-nut-, and palm-kernel-oils, are used either alone, or in various combinations, for the different kinds of mottled soap. The raw materials for soaps for special manufacturing, toilet, and other purposes, will be mentioned when treating of those soaps.

It has been already noticed that coco-nut- and palm-kernel-oils combine with a larger quantity of soda than any other known fat, and hence that the yield of soap from these oils is greater than from other fats. Further, the soap so produced has the power of combining (and making a hard soap) with more water than can ever be communicated to tallow soap, a property which has frequently given rise to dishonest traffic. This soap is more soluble in water than any other, and requires a much larger quantity of common salt to separate the excess of water from it. In technical language, it is said to "work close." Reference to the table on p. 1765 will show the reason for this. Coco-nut-oil contains a number of low terms of the fatty-acid series, whose salts are so very soluble, that even the lime and baryta salts of the lower among them are quite soluble in water, just as are the lime and baryta salts of formic and acetic acids, the lowest terms of all.

Among the raw materials used by the soap-boiler, not enumerated under Oils, are various bye-products of other manufactures, among which may be mentioned—the oleine or oleic-acid from candle-works (see Candles, pp. 580, 584, &c.); the grease recovered from washwaters of woollen factories, pp. 1155–6, which is very apt to contain unsaponifiable oils, and should be employed with caution; the "foots" from various oil-refineries, which either contain strong mineral acids (p. 1460) or are partly-formed soaps when an alkaline refining process has been used (p. 1460); waste fats recovered by carbon bisulphide or petroleum-spirit (pp. 1454–5), also liable to contain unsaponifiable oils; "suint," or the grease derived from natural wool, accompanied by potash salts; and, especially in France, the yolks of eggs, see pp. 1365–6 (of which the whites have been used in the preparation of albumen), which contain a considerable percentage of fatty matter. This list might be largely increased.

The value of soap-making material is best ascertained by saponifying a weighed quantity (say 5-10 *grm.*) with soda, dissolving the soap in water, decomposing it with a mineral acid, and then washing, drying, weighing, and examining the resultant fatty acids, as is described on pp. 1462–3 of Oils, and, in a modified form, on p. 1794 of this article.

Rosin (see Resinous and Gummy Substances, p. 1680).—The kind used in soap-making is known as colophony. The lighter shades only can be used for better-class soaps. Such are liable to contain a little turpentine, which, to some slight extent, injuriously affects the hardness of the soap; and they are apt to become unpleasantly soft in very hot weather. Opaque rosins contain turpentine, and, in rare cases, water. Dark rosins may be improved in colour, and deprived of suspended impurity, by being melted, allowed to settle, and then boiled on a weak solution of common salt. Dark rosin may be distilled with steam under a pressure of 10 atmos. to make it nearly white for soap-making. Like many other distilled products, however, it has a tendency, both alone and in combination, to oxidize rapidly, and deteriorate in colour. When fine rosin is unusually dear, however, this process may be employed with advantage.

Chemically speaking, rosin is an acid, or mixture of acids (picric, sylvic, colophonic, and pimaric) whose general formula is $C_{20}H_{30}O_2$, and their combining proportion (with 31 parts soda) is 302. Rosin decomposes carbonate of soda, and combines instantly with caustic alkali, forming in each case a so-called rosin soap, which is a thick, slimy, brown mass, containing 15·8 per cent. of dry soda; its attraction for water is so great as to become liquid on exposure to air, even though previously dried artificially.

Rosin is never employed alone for soap, but always in conjunction with fats; it has been described as an ameliorator, and is also a cheapener; it contributes to the popular qualities of soap, rendering it more readily soluble, and forming a copious lather in laundry and household soaps. In them the proportion varies from 15-20 per cent. of the fatty matter employed, to an equal weight, or even more. Hard soaps for manufacturing purposes rarely contain it. It may be saponified alone and the result mixed with a fat-soap in due proportion, or the whole may be saponified together. The result is the same, and the choice of methods depends upon convenience in working; but the former is preferable with impure rosin, in order to give it as many changes of leys as possible, and thus to wash out suspended impurities, such as leaves, bits of stick, &c., all of which discolour the product.

Alkali (see Caustic Potash, pp. 251–3, Carbonate of Potash, pp. 253–60, Caustic Soda and Carbonate of Soda, pp. 279–309).—In connection with their application to soap manufacture, it may be mentioned here that all large English soap-makers make their own soda, either from common salt, or from "salt-cake" (sulphate of soda), and causticize at once the liquor formed by the lixiviation of the black-ash. Nearly all the soda used in American and Colonial soaperies is bought in the English market, and imported either as soda-ash or caustic soda. The process of preparing solution of caustic soda or "leys" from soda-ash (or black-ash) is described on p. 307. It is only necessary to add a word of caution to the soap-maker as to the way of dealing with the solution when made. The reason for conducting the operation in so weak a solution as is directed (about 22° Tw., or 1·110 sp. gr.) is, that only under those conditions will carbonate of soda part with its carbonic acid to caustic lime. At higher specific gravities the reaction may even be reversed, and caustic soda will remove carbonic acid from carbonate of lime. It is of the utmost importance to the soap-maker to causticize his leys as completely as possible, *and to keep them so*, since (unless his soap be made entirely from fatty acids, a very rare thing) any carbonate of soda in his leys is simply so much soda wasted. The caustic soda ley should, therefore, only be prepared as it is wanted for use, and when stored should be kept in covered vessels to which air has no access; shallow open tanks should be avoided at all hazards. If, as is frequently the case, stronger ley is required than that produced in the original operation, it should be concentrated by evaporation in open vessels, or by dissolving in it some solid caustic soda. It should be specially noted that for concentrating or storing solution beyond 30° Tw. (sp. gr. 1·150), cast-iron vessels alone should be employed, owing to the solvent action of soda upon wrought-iron.

It may be laid down as an axiom that no ley is sufficiently causticized which liberates bubbles of gas, when a small portion of the clear cold ley has an excess (i. e. more than sufficient to neutralize it and to turn blue litmus red) of mineral acid added to it. This is a sufficiently good test for a foreman to work by.

In the case of nearly pure solutions of caustic soda, a very close approximation to their strength,

i. e. their percentage of caustic soda, may be obtained by the observation of their density or by an hydrometer (Fig. 1, p. 2). These instruments are usually made very cheaply of glass, the lower end being weighted with shot or mercury. When floated, they displace their own weight of liquid, and hence the bulk displaced varies with the sp. gr. of the liquid examined, which is indicated on the stem of the instrument. Two scales are in use among soap-makers, those of Twaddell and of Baumé. The zero point of both is that to which the instrument sinks in distilled water at 15·5° (60° F.). It must not be forgotten that increase of temperature in a fluid, by increasing its bulk, diminishes its sp. gr. All sp. grs. quoted in this article are at 15½° (60° F.).

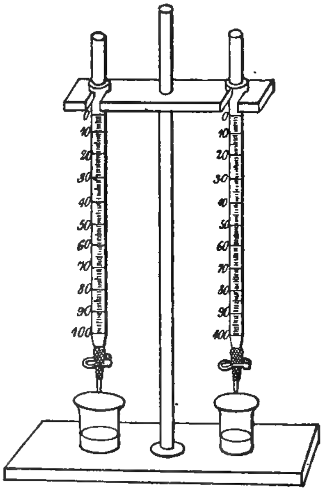
The following table gives the means of comparing degrees Tw. and Baumé with each other and with actual sp. gr.; and also gives the approximate percentages of caustic soda and caustic potash in solutions of that sp. gr. *containing no other salts.*

Degrees Tw.	Degrees Baumé.	Specific Gravity.	Per cent. of Caustic Soda.	Per cent. of Caustic Potash.
5·2	3	1·026	1·81	2·83
7·5	5	1·037	2·72	3·96
11·8	7	1·059	4·23	6·21
14·0	10	1·070	5·44	7·36
19·8	12	1·094	6·65	9·62
23·6	15	1·118	7·86	11·82
26·2	17	1·131	9·07	13·01
32·6	20	1·163	10·88	15·84
42·4	25	1·212	13·90	19·80
53·0	30	1·265	17·52	23·76
64·2	35	1·321	22·97	27·72
78·0	40	1·390	27·50	32·40

It may be noted here that for every 31 parts of pure soda required in any operation, 53 parts of pure dry carbonate of soda, or 143 parts crystals (the soda-crystals or "Scotch soda" of commerce), are required, and that the corresponding quantities of caustic and carbonate of potash necessary to do the same work are respectively 47 and 69 parts by weight. With this basis, a simple proportion sum will show in any given form the quantity of alkali required for any purpose.

It cannot be too strongly impressed upon the young soap-maker, however, that the indications of the hydrometer as regards the alkaline strength of his leys are only reliable in the case of *pure* solutions. When the leys contain much carbonate, sulphate, or other alkaline salts, and especially common salt, as the "half-spent" leys always do, the quantity of alkali must be determined by a more scientific method. This operation consists in ascertaining how much acid of known strength is necessary to neutralize a given quantity of the leys, and is very fully described in books upon volumetric analysis or alkalimetry. It is also referred to in Alkali, pp. 301–2. The apparatus employed is chiefly a burette (Fig. 1237), with pinch-cock to regulate the flow of liquid,—and graduated, usually, into cub. cent. The standard acid solution may be crystallized oxalic acid (63 *grm.* in 1 *litre* or 1000 *cc.*), sulphuric acid, or even nitric acid. If oxalic acid of the above strength be used, every *cc.* corresponds to 0·031 *grm.* of soda. A known weight of the leys (or ash) to be examined is taken in a glass flask, diluted with, or dissolved in, water, a few drops of tincture of litmus added, the whole boiled, and the acid solution added little by little until, after a few seconds' boiling, a permanent faint-red colour is obtained in the solution. The number of *cc.* used is then read off, and the proportion of soda (or potash) is calculated from this. It should be noted that, in this operation, all carbonate, aluminate, silicate, and sulphite of soda (or potash) test as "available alkali." The determination of carbonic acid may be effected in various ways, the principle common to nearly all of them being to expose a known weight of alkali to the action of an excess of acid in a flask, under such conditions that the carbonic acid escapes in a dry state, and the loss in weight indicates its quantity. For further details, as well as for methods of completely analysing leys or solid alkali, works upon analysis should be consulted.

1237.



Lime.—It is very important that the lime used by the soap-boiler should be as pure as possible, and it is highly desirable to use it when freshly burnt. When this cannot be obtained, it should be kept in well-closed casks, avoiding access of air, which contains carbonic acid, and therefore destroys its power of causticizing alkali. It should contain but little, if any, alumina, magnesia, or silica, and should "slack" readily with water; in fact only what is technically called "fat" lime should be used. Since 28 parts of pure lime are equivalent to 31 parts of pure soda, the quantity of lime necessary for causticizing a given quantity of ash may be calculated, but in manufacturing operations, at least 10 per cent. excess of lime should be used. A clear solution of lime in water may be used for testing the causticity of leys, since any carbonated alkali shows its presence by a cloudy deposit of carbonate of lime.

Water.—The purity of the water employed in the factory is a matter of great moment to the soap-boiler. As a rule, spring-water should be avoided, and river- or lake-water employed whenever possible. If it contains suspended impurities, these should invariably be removed by subsidence or filtration. Organic impurities, if colourless, may be disregarded. The great enemies of the soap-maker are the soluble salts of lime of alkaline earths, and sometimes even of metals, occurring in natural waters, because all these bases form *insoluble soaps* in the soap-copper, and use up large quantities of fat to no purpose, since these insoluble soaps are of no market value themselves, and if disseminated in a marketable soap, injure its appearance greatly. The hardness of water may be determined by "Clark's test," in which an alcoholic solution of pure soap is employed. The amount of soap wasted by hard waters may be ascertained from this table, in which the hardness is supposed to be caused simply by lime salts.

Degree of Hardness.	In 1000 lb Water.		Soap decomposed by 1000 lb. Water.
	Lime.	Gypsum.	
	lb.	lb.	lb.
5°	0·25	0·61	3·66
10	0·50	1·23	7·31
15	0·76	1·84	11·12
20	1·01	2·45	14·75

If no other than hard water is available, one of the various plans for softening it should be adopted under the guidance of a chemist, such as the addition to the water of milk of lime, either alone or with chloride of barium, or of silicate of soda.

Salt.—As will be seen in the sequel, common salt plays a very important part in soap-boiling, and what has been said with regard to water applies equally to it. The purest kind is rock-salt freed from insoluble matter; next in order comes salt from brine-springs; while sea-salt contains so many other salts besides sodium chloride, especially magnesium chloride, that it should be avoided if possible. When that is not the case, it should be dissolved in water, and the magnesia removed by the addition of silicate of soda, when the insoluble silicate of magnesia should be allowed to subside before the brine is used. In connection with salt, it will be found convenient to remember that strong brine or a saturated solution of salt contains one-fourth its weight or 25 per cent. of sodium chloride, that its sp. gr. is 25° B., and that if nothing else be present in solution, every degree Baumé of sp. gr. corresponds to 1 per cent. of salt.

It will be convenient here to consider a certain physico-chemical property of soaps, of great practical importance to the soap-boiler. The property referred to is the behaviour of soap to various saline solutions, and although not instrumental in the formation of soap, it is almost essential in separating the foreign matters that would otherwise render hard soap impure, and it is also influential in controlling the amount of water in soap. Although soda soaps are soluble in water, they are not soluble in a solution of common salt, nor of caustic soda. If, therefore, common salt be added to a solution of soap (or even of partially saponified fat) in water, the salt dissolves, and turns the soap out from its state of solution, in small flakes which collect together, and float on the surface of the salt solution, by virtue of their less sp. gr. The same thing happens when a strong solution of caustic soda is added to soap in an aqueous solution, or, more gradually when a solution of soap in water containing excess of caustic-soda, or some amount of sodium chloride, is concentrated by the evaporation of its water, as when a soap-copper is boiled by fire or close steam. The addition of salt (or of strong leys), therefore, to soap containing an excess of water, removes the superfluous water, and in chemical language, precipitates the soap from it. Soap so precipitated contains 35–40 per cent. of water. When the fatty matter employed contains coco-nut- or palm-kernel-oils, more salt (or soda-leys) is required for this operation than when those oils are not used.

It may also be noted here that if sodium chloride be added to a potash soap in solution, an interchange of acids and bases takes place, soda soap being formed, and potassium chloride left in the solution. This process has been actually used in Germany for the fabrication of hard soaps.

Manufacture.—Before proceeding to describe this on a large scale, where operations involving considerable mechanical, physical, and chemical knowledge are conducted with a view to produce the best possible article at the lowest cost, a short space will be devoted to instructions for making small quantities of soap of inferior appearance, which will answer well for homely purposes, for the benefit of those living far from large towns, and who may yet have on their farms or stations many of the ingredients necessary for their production.

For those who have plenty of fat or oil at command, but no alkali, the small canisters of pure powdered caustic soda and caustic potash, sold by the Greenbank Alkali Co., St. Helen's, will be found very convenient. With these products, soaps can be made without any boiling. For a hard soap, dissolve 10 lb. of this soda in 4 gal. of water, and allow the leys to cool. Take 75 lb. of clean fat or oil, rendered fluid by heat if necessary, and when it feels just warm to the hand, add the leys to it in an uninterrupted stream, stirring well all the time; continue the stirring for 15 or 20 minutes, and then set aside in a warm place for a day. In this interval, the soda reacts upon the fat, and turns out its glycerine, which remains in the soap. Any impurities in the fat used, or any salt or other extraneous substance, will be apt to spoil the operation. For soft soap, use 20 lb. of this caustic potash, dissolved in 3½ gal. of water, and mix as above with 8¾ gal. of cotton-seed, fish, or other (non-mineral) oil. For a harder soap, one or more of the gallons of oil may be replaced by 10 lb. (or a multiple thereof) of tallow.

A very firm soap may be made on a small scale from the oleic acid from candle-factories, known commercially as oleine or red-oil, by heating it to about 100° (212° F.), and adding thereto one-half its weight of caustic soda leys at 36° B. The combination takes place instantaneously, and it is only necessary to allow the soap to get cold, when it is fit for use. For the preparation of the leys, see p. 1767. They need not be perfectly caustic, but if any carbonate of soda be present, they must be of proportionately higher sp. gr., and the vessels employed must be capacious, in consequence of the effervescence that occurs.

Hard soaps may also be made on a small scale without boiling, by adding to a mixture of 2 parts tallow and 1 part coco-nut-oil, or of 3 parts tallow and 2 parts coco-nut-oil, one-half its weight of caustic soda leys at 36° B., the whole being at a temperature of 55°–60° (130°–140° F.); the mixing, after being well stirred, should be set aside for a day or two. Here also the presence of common salt is a serious obstacle to the combination.

Soaps that require boiling cannot be well prepared in small quantities. Those who wish to make them, however, would do well to study the description of the process on a large scale. In making small quantities of hard soap, it will be well to boil together the fat and the soda leys previously well causticized by lime, and to calculate from the table on p. 1768 how much leys is necessary, taking as a basis that for every 10 lb. of fat, about 1 lb., or rather less, of pure soda (100 per cent.) is required. Combination will not take place unless the solution is quite weak, say 12° B., and when it is effected, salt may be added to separate the excess of water. The salt should be sprinkled in gradually, time being allowed for each portion to dissolve, and when a small sample, taken out on a shovel and allowed to cool, separates into liquor and soap, enough salt is added; the boiling should then be stopped, and the whole allowed to repose; in an hour's time, the soap may be skimmed off. Soft soap is more easily made by boiling on a small scale, since the process is the same whatever quantities of materials are employed. The reader is, therefore, referred to p. 1776 for instructions under this head.

In considering the manufacture of soap in large quantities, the subject may be conveniently and naturally divided under the following heads:—

I. The apparatus and processes employed in effecting the chemical combination between the fatty matter and alkali, including in this a general description of the mode of boiling (or otherwise preparing) soaps of different types.

II. The machinery and mechanical and physical contrivances made use of in converting the chemical compound so produced into a marketable soap.

III. Ingredients and formulæ for the production of special kinds of soaps for particular purposes, including toilet soaps, manufacturers' soaps, &c.

IV. Theory of the action of soap; methods for its analysis and valuation.

V. General considerations of the industry—its location, prospects, legislative condition, &c.

It will be convenient to treat, in the order of their complexity, the somewhat extensive range of subjects included under I., commencing with the simplest, and accordingly we find the following natural sub-divisions:

I *a*. Soaps produced by the direct union of fatty acids and caustic alkali, or by the decomposition of carbonated alkali by fatty acids.

I *b*. Soaps produced by the action of the precise quantity of alkali necessary for saponification upon a neutral fat, without the separation of any waste liquor, the glycerine being retained in the soap. This class includes—*α*. Soaps made by the "cold process," *β*. Soaps made under pressure.

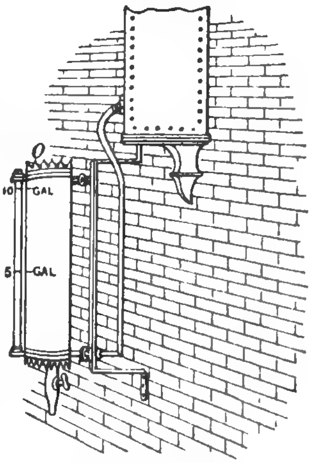
I *c*. Soaps produced by the ordinary methods of boiling in open vessels, working with indefinite quantities of alkaline leys, the processes being controlled by the experience of the operator. These are again subdivided into—α. Soft soaps, in which the glycerine is retained, potash being the base; β. The so-called "hydrated" soaps, in which the glycerine is retained, and of which "marine" soap may be taken as the type; γ. Hard soaps, with soda for a base, in which the glycerine is eliminated, comprising three kinds—curd, mottled, and yellow soaps.

It may be noted that a very large proportion of all the soaps manufactured is included in this last and most complex subdivision, since practical experience shows that, all things being considered, they are the most marketable.

Full directions for the fabrication of these several kinds will now be given, the paragraphs treating of each being numbered to correspond with the above classification.

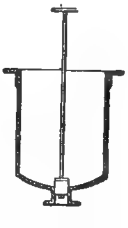
I *a*. In soaps made from fatty acids, the soda is used in the form of a refined carbonated ash at 52° (that prepared by the Jarrow Co., Newcastle-on-Tyne, is recommended), every 100 lb. being dissolved in 160 lb. water in a lead-lined vat, and the solution allowed to settle previous to use. The store-tanks of this, and of the fatty acids employed, are connected with small gauge-tanks or measuring-tubes (Fig. 1238), for the purpose of obtaining uniformity in the results by the use of exact quantities in every operation. For the delivery of the soda solutions into the soap-pan, a special feeder (Fig. 1239) is provided, closed with a movable tampon, by which the flow of liquid may be regulated at discretion; a perforated rose-spout may be advantageously placed under the exit-pipe.

1238.



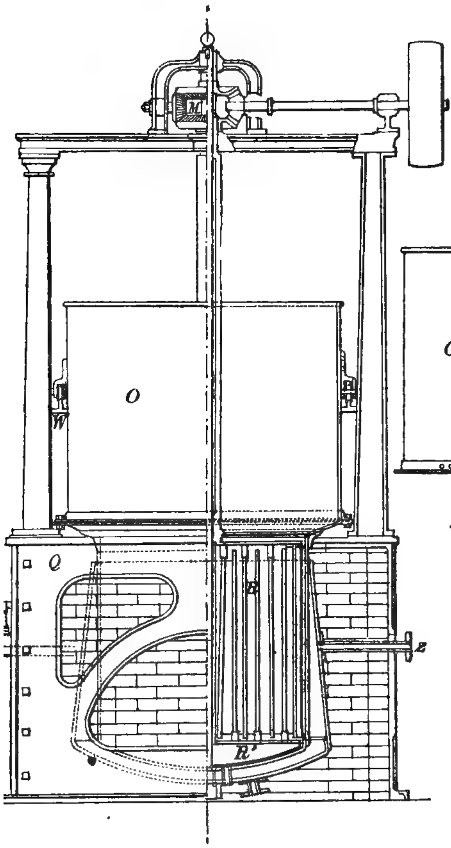
The soap-pan in which the operation is conducted, shown in Figs. 1240–2, is jacketed, the inlet-pipe being at Z, and the steam is either superheated, or used at a pressure of 75–80 lb. Above the pan, is a movable curb O, with slide at *m*, necessary to give room for the intumescence caused by the liberated carbonic acid; a wheel arrangement W enables it to be readily drawn aside on a railway behind the columns N, which support the gearing M. This gearing moves the stirrer R at the rate of 40 rev. a minute; the latter is made of wrought-iron, and is most efficient when the two sets of blades move in opposite directions; when this is not the case, the pan itself should be provided with fixed traverses armed with vertical cross-teeth. In making soap with this apparatus, 1000 lb. oil are run into the pan with the curb O in its place, and heated to 138°–160° (280°–320° F.), according to its quality. At this point, 190 lb. of soda ash for a neutral soap, or 210–225 lb. for a strong soap, dissolved in the proper quantity of water, and at 100° (212° F.), is let into the pan at such a speed that it occupies not less than 6 nor more than 12 minutes. The whole is well stirred meanwhile, and swells up enormously; but 5 minutes after the last portions of alkali have been added, the mass subsides, and, in 15 minutes more, changes from a spongy to a clear, soft, brilliant, homogeneous paste. The curb is then removed, and, in about an hour, 100 lb. of boiling water is let in from the rose-spout of the soda-feeder, and the whole is again well stirred; if it be desired to mix silicate of soda or anything else with the soap, it is added at this stage, after which, the soap is transferred to the cooling-frames (pp. 1781–2), and a fresh batch is proceeded with. Soap thus made has the following composition:—Oleic acid, 65·00; soda, 6·7–7·50; water, 27·50. When rosin is used, it should be added to the oil while the latter is being heated; or the rosin soap may be made in a separate pan, provided with a Morfit's steam-twirl (Fig. 1243), in which the tubular blades of the stirrer are perforated to emit steam while the whole is in motion; 1200 lb. rosin and 2200 lb. caustic leys at 11° B. are boiled together, and the thin jelly so produced is transferred in suitable quantities to other pans. It contains:—Rosin, 54·5; soda, 7·8; water, 37·7. The apparatus described here is also suitable for several other kinds of soap, the steam-twirl, &c., being especially useful for making "hydrated" soaps (p. 1777).

1239.

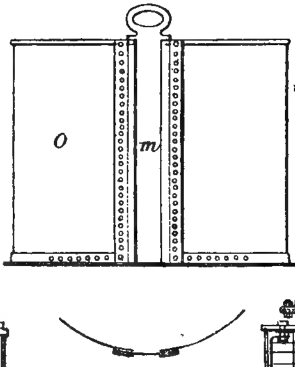


I, *b*, α.—The so-called "cold process" consists in mixing given weights of fat, or a mixture of fats, previously melted at as low a temperature as possible, with caustic soda solution of a given sp. gr., the quantities of each being so adjusted that only just enough soda shall be present to completely saponify the fat. After thorough incorporation, the mixture is covered up, and allowed to stand. In a few hours, the chemical reaction commences, accompanied by considerable evolution of heat, and the soap is formed. After the lapse of 2 or 3 days, it is usually hard enough for use. It is obvious that soaps made in this way retain all the glycerine originally combined with the fatty acids, disseminated through the particles of soap. This, and the comparatively low temperature at which the soap is made, are the chief reasons why this process is much in vogue for the cheaper kinds of toilet soap, since the perfumes employed are not dissipated by heat. It is found, however, that soaps thus prepared are very apt to contain an excess of alkali, and hence they are unavailable where perfectly neutral soaps are required.

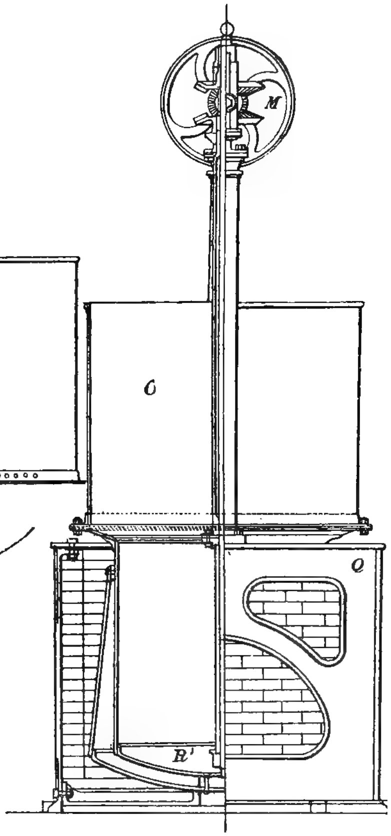
1240.



1242.



1241.



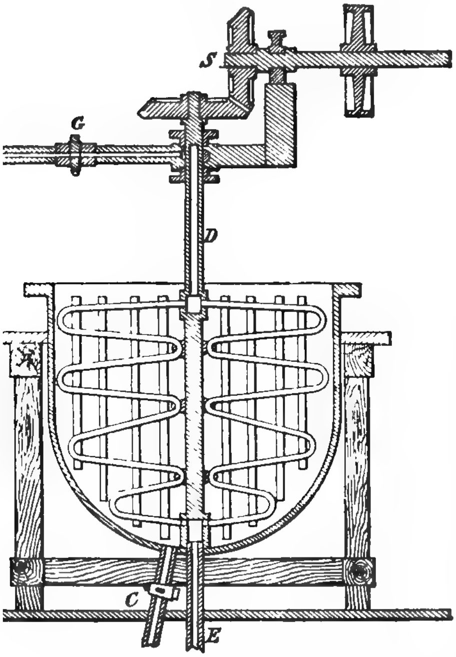
Another objection is, that, as there is no opportunity of removing any extraneous matter, the materials employed must be of the purest, and as the soda leys are usually required in a concentrated (and therefore expensive) form, the process is not so advantageous as at first sight appears. It is chiefly applicable to soaps made on a small scale; when larger quantities are operated on, a mechanical agitator, such as Hawes' boiler, represented in Fig. 1244, is necessary. This, for operating on 2½ tons of tallow, is a cylinder 6 ft. diam., 12 ft. long, with a central shaft provided with radiating arms, set in rotation by any convenient mechanism. Any saponifiable fat or oil may be used, and for every 100 lb. of the pure fat, 50 lb. of caustic leys at 36° B. should be taken. When these are not very pure, i. e. if they contain much extraneous soda salts, especially sodium chloride, saponification will not take place, unless some proportion (10 per cent. on the fat, at least) of coco-nut-oil be used. The following mixtures will be found useful for this process:—

	Tallow.	Lard.	Palm-oil.	Coco-nut-oil.	Rosin.
(1)	100	..	..	..	..
(2)	100	..	..	50	..
(3)	..	..	55	55	100
(4)	50	30	20	..	..
(5)	..	100	..	..	..

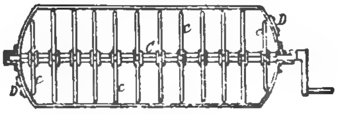
Nos. 1, 2, and 5 make good toilet soaps, which are improved if about ¼ of the soda used is replaced by an equivalent quantity of potash. No. 4 with unbleached palm-oil gives a fine yellow soap, liable however to bleach in the light. No. 3 is given on the authority of Cristiani, who recommends the use of 100 lb. leys at 25° B. to the 210 lb. mixed fat and rosin.

The time required increases with the amount of materials operated on at one time. The chief points needing attention are, to use pure materials, to avoid excess of alkali, and so to manage the temperature and the stirring as to make a complete mixture of the melted fat and leys, that will not separate before saponification takes place.

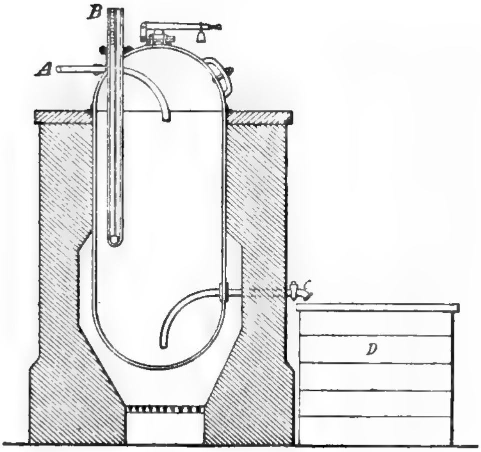
1243.



1244.



1245.

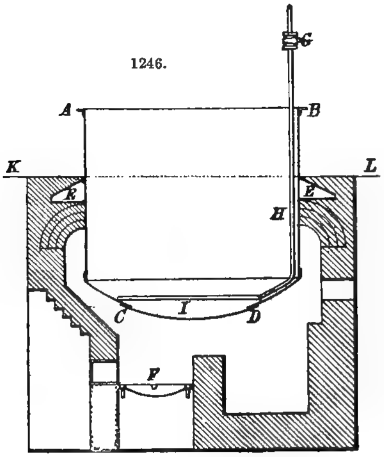


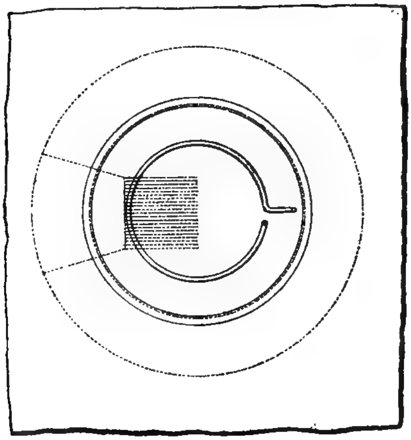
I, *b*, *β*.—In this class, are the soaps produced by boiling under pressure. This process has been the subject of numerous patents at various times, all having for their object the shortening of the time occupied in the ordinary methods of open boiling (I. *c*.), and the saving of the salt employed therein. In this case, also, the quality of alkali employed, whether caustic or carbonate, is accurately adjusted to the fat to be saponified, and the glycerine is retained in the ultimate product; mixtures of any saponifiable fats and resins may be employed. The kind of apparatus used is shown in Fig. 1245; and it consists of a steam boiler provided with a man-hole and safety-valve, with a feed-pipe A and discharge-pipe C, and with a long thermometer B, in a pocket filled with paraffin. The proper quantities of fat and caustic leys are let in through A; all taps are closed; a fire is kindled, and maintained until the thermometer rises to about 154°·4 (310° F.), equivalent to a steam pressure of 63 lb. a sq. in. When it has remained at this point for an hour, the tap at C may be opened, and the contents discharged into a cooling-frame D, by the steam pressure in the boiler. For a good yellow soap, 7 cwt. tallow, 3 cwt. palm-oil, 3 cwt. rosin, and 140–150 gal. caustic soda leys at 21° B. are recommended by the inventor, Dunn. Another formula is 800 lb. tallow, 200 lb. palm-oil, 400 lb. rosin, 175 gal. caustic soda leys at 25° B., for one hour at 122°·2 (252° F.), or 17 lb. steam pressure. It is obvious that this will make a drier soap, since leys at 25° B. contain less water than leys at 21° B., and that the quantity of water desired in this product can thus be regulated to a nicety. In 1865, Bennett and Gibbs, of Buffalo, New York, took out a patent for effecting this operation with carbonated alkali, thus avoiding the expense of causticizing. Their boiler is similar to that shown in Fig. 1245, but is placed horizontally, and provided with an agitator similar to that for Hawes' boiler. The process requires a higher temperature and pressure than the previous one, ranging from 176°·6 to 204°·4 (350°–404° F.), or 220–280 lb. a sq. in. The outlet-pipe is provided with a safety-valve, and the inventors state that if this be loaded to about 250 lb. a sq. in., and the raw materials be pumped in at one end, the process may be made continuous, finished soap coming from the outlet, produced in less than one hour from the introduction of the raw materials. The formula recommended is for every 100 lb. of saponifiable fat, 30–33 lb. of soda-ash of 48 per cent. dissolved in 100 lb. water. In the early stages of the process, the liberated carbonic acid is allowed egress by one of the safety-valves, and if any liquid escapes before a temperature of 163° (325° F.) is reached, it should be returned to the cylinder. The following advantages over ordinary processes are claimed :—(1) Rapidity of manufacture, (2) improvement in quality, (3) increased yield of soap, (4) economy of labour, (5) saving of fuel, (6) use of cheaper fatty material, (7) saponification of the whole of it, (8) uniform certainty of results, (9) retention of glycerine, and improvement of product thereby, (10) ability to use carbonated alkali. It is obvious, however, that the risk of explosion is not slight, and the practical difficulty of working the agitator at that temperature and pressure must be considerable.

I, *c*, *a*. *Soft Soaps.*—The production of these is the simplest case of the process most usually adopted in the fabrication of soap, viz. boiling in open vessels, technically termed "coppers," with the aid of steam (either wet or superheated) or of fire, or of the two simultaneously. It will be convenient, therefore, to describe here the construction and fittings of the various kinds of soap-coppers (or soap-pans), and the different modes in which steam and fire are applied to boil their contents.

In the days when there was an excise duty upon soap, "coppers" were usually of what is now considered a very small size, and were constructed of cast iron; they consisted of hemispherical pans, upon which were mounted as many cylindrical rings as were necessary to make the copper of a suitable depth, usually about twice its diameter; the rings were joined to each other, and to the hemispherical bottom, with cement joints. There was no limit to their size, except the difficulty of making large castings, and they were usually encased in masonry, and fitted with fire-places and flues in the manner to be presently described for modern wrought-iron "coppers." In the case of

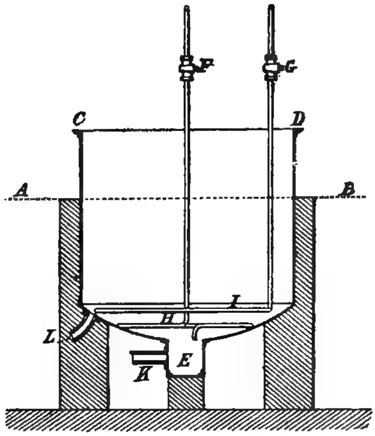
1246.

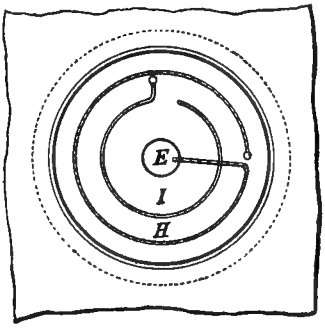




1247.

1248.



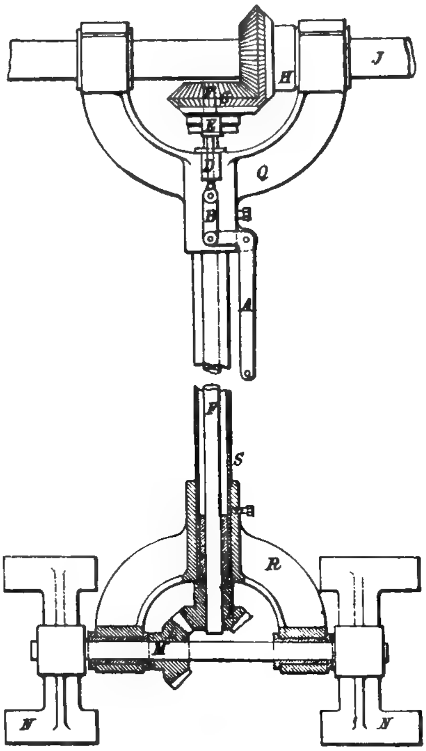


1249.

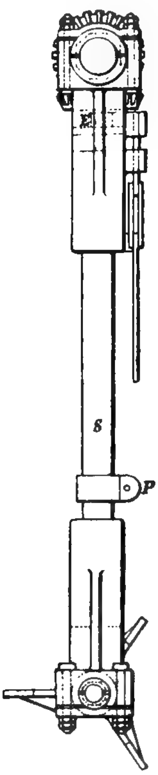
those boiled by fire (the only method until steam-boiling was introduced), the hemispherical bottoms were very apt to crack from overheating, and from many other causes, which it is scarcely necessary to detail, as these pans are fast becoming obsolete.

The removal of the excise duty in England, in 1853, gave an enormous impetus to the soap industry. Manufacturers were no longer deterred from making large batches of soap by the fear that, if they were spoiled, double duty would have to be paid when they were re-made and produced fit for sale; and, as a natural consequence, numerous experiments were tried, both with the raw materials and the apparatus employed. Soap-coppers are now made of colossal size, those capable of turning out 50 tons of finished soap (112,000 lb.) at one operation being by no means uncommon, and some of the large American manufacturers have built even still larger coppers, requiring a building of 3 stories to contain them. Although it is desirable that those boiled by fire should be circular in shape, and not too large—say 20 tons capacity—the coppers whose contents are boiled by steam may be of any desired shape, circular, oval, or rectangular, provided that the steam-pipes be carried into the corners (if any), and be so arranged as to ensure uniformity of ebullition throughout the whole mass. There is no necessary proportion between diameter (or superficial area) and depth ; English soap-makers are more accustomed to pans whose diameter is to their depth as 1 to 1, 1 to 1·25, or 1 to 1·5 (e. g. a pan 15 ft. diam. and 15 ft. deep will turn out 25–30 tons of soap); while their American confrères, less trammelled by tradition, increase the ratio as far as 1 to 2, 1 to 2·5, or even 1 to 3.

1250.



1251.



Soap-coppers are now almost invariably built of wrought-iron plates, and rivetted together in the place where they are eventually to stand. Figs. 1246, 1247 show a simple form of copper for fire-boiling, with the fire-place, flues, &c.; A B D C is the outline of the copper, C D being a circular renewable plate, in the part most exposed to the action of the fire F. At E, are supporting lugs of cast-iron; K L is the floor-level; H I, a steam-pipe ending in a perforated coil, steam being controlled by the cock at G. Figs. 1248, 1249 show a copper where steam only is used: A B is the floor line; C D E, the copper, provided with a "hat" at E to receive impurities that subside, and to enable spent leys to be removed completely by the draw-off at K. Another draw-off is fitted at L. Two steam-worms are provided, H, with cock F, whose coil is perforated, admitting "open" or "wet" steam among the copper contents, and I, with cock G, in which high pressure or superheated steam is circulated, for use when it is desired to evaporate water. This last coil is usually omitted in the largest coppers, being only used in making curd and mottled soaps.

An important adjunct to a soap-copper is a little piece of machinery for preventing the contents from boiling over, as they are apt to do when saponification is taking place, and also in a later stage, even after the steam is turned off. It is called a fan, and is represented in Figs. 1250, 1251 ; it consists essentially of a rotating paddle, whose blades just touch the top of the boiling mass. The motion is derived from an overhead shaft J, on which is keyed a bevel-wheel H, gearing into a similar wheel G ; this latter slides on a feather on the shaft F, being thrown in or out of gear by a fork E, to which is attached a rod C, actuated by links B and bell-crank A, in the bottom end of which is an eye for attaching a cord which may be drawn to right or left. The lower end of the fan-shaft drives the over-shaft M, on which the fans N are keyed by means of bevel-wheels K L. The top and bottom of the fan-shaft are carried by bushes driven in at each end of a piece of stout 2-in. steam-pipe, and the pipe S is inserted in cast-iron frames Q R. Near the lower end of the pipe, is a shackle P, to which a rope or chain is attached for lowering or raising the fan, according to the surface of liquid in the copper. The whole swings on the axis of shaft J.

The fabrication of soft soaps will now be described. Soft soap is a more or less impure solution of potash soap mixed with glycerine in caustic-leys, and forming at ordinary temperatures a transparent smeary jelly, containing at times, and especially in cold weather, white grains, which are impure stearates of soda or potash. The most suitable form of copper for making it is shown in Fig. 1246. In England, whale-, seal-, and linseed-oils are chiefly used, and occasionally a little tallow to produce the grains, or "figging," just described, an appearance which serves no really useful purpose. On the European continent, hempseed-, linseed-, camelina-, and poppy-oils are used, and also rapeseed- and train-oils, especially in summer, since they produce a harder soap. In America, cotton-seed-oil, and oleic acid, are often employed. Hempseed-oil gives a greenish tint much prized by consumers, which may be imitated by the addition of a little indigo precipitated by potash from its solution in sulphuric acid.

A very desirable, but not necessary, adjunct to the soap-copper is a set of tanks of iron or wood, whose contents per inch of depth are known, in order that the quantities of oil and leys let into the copper may be regulated. In many large factories, the practice is to keep a strict account of the quantity of fatty matter and rosin used, but to control the amount of leys according to the judgment of the soap-boiler. Such gauge- and store-tanks may be in any convenient place, and pipes or open shutes carried from them to deliver their contents into the copper; suitable plugs and cocks control the flow of the liquid at the pleasure of the operator.

To make an unsophisticated soft soap, a suitable quantity of oil is run into the copper, not exceeding ¼ its total capacity; at the same time, potash leys at 9°–11° B., not absolutely caustic, but retaining some potassium carbonate, are let in, and the steam is turned on, or the fire kindled, or both; the fan may also be adjusted at the height beyond which the soap is not to boil, and the whole is carefully watched. If the copper has not boiled until a volume of leys has run in equal to that of the fat, the stream of leys should be stopped, and started again when the ebullition commences. If the oil and leys do not appear to have combined, the fire should be checked, the stream of leys stopped, and gentle steam-boiling continued until this is the case. It is very difficult, especially with rape-oil, to get the alkali to combine, but when once the process has begun, it goes on with tolerable rapidity with subsequent additions of leys. From time to time, small samples of the soap are dropped upon a glass plate, and after cooling at a temperature as near 8° (46°·4 F.) as can be obtained, are carefully examined. The soap is good if it is clear and translucent; a fatty border indicates deficiency of alkali; while if the sample be granular, grey, and lustreless, too much ley has been added, a fault that must be corrected by the addition of more oil, previously mixed with leys at 2° B. Should the sample separate on the glass into soap and clear liquor, the quantity of leys is excessive. If the combination be good, and alkali deficient, stronger ley (at first 15°–16°., then 23°–25° B.) may be cautiously added; a sign of saturation, or rather slight excess of alkali, is the appearance of a striped skin, or ley-veins, on the surface of the sample. When it is judged that enough alkali is present, the steam is turned off, and a certain amount of water is evaporated by boiling the copper with fire, during which operation the bubbles get larger, the soap being almost laminated, and make so much noise in their escape that the boiler's phrase is " the soap talks."

When finished, a small sample must not glide or be slippery on the glass, nor must it draw into threads when worked up between the fingers and thumb; a very small ring should appear in the sample in 12–15 min., indicating the necessary slight excess of potash. The soap is filled into barrels while quite hot, and to promote rapid cooling of the mass, cold soap is often added.

A somewhat shorter method, saving the evaporation in the later stages, has been introduced of late. For every 100 lb. oil, 200 lb. leys at 20° B. are required; when liquid fats are used, this quantity is run in at the commencement of the operation; with solid fats, ½ may be taken, and when thoroughly incorporated, the rest may be added, and the soap boiled as previously described.

If it be desired to make a soft-soap in which some of the potash is replaced by soda, the proportions of the two leys must be accurately adjusted to each other, and to that of the fat used. The process was first worked out by Gentele, and improved by Cristiani, who recommends for the saponification of oil by ⅗ potash and ⅖ soda the following formula:—5000 lb. oil, 2674 lb. potash ley at 20 B., 740 lb. potash ley at 25° B., and 2353 lb. soda ley at 20° B. If enough steam be not condensed in the boiling, water may be added to make the whole weigh 12,500 lb.

To produce a grained soft-soap (or " fig"), it is essential to use pure potash leys, and to employ some hard fat, the stearic or palmitic acids of which form potash salts whose crystallization produces the grains, within somewhat narrow limits of temperature, viz. 9° (48°·2 F.) and 15°

(50° F.). The following fat mixtures will produce it:—(*a*) 55 palm-oil, 45 oleic acid; (*b*) 55 palm-oil, 15 tallow, 30 linseed-oil; (*c*) 70 palm-oil, 30 linseed-oil. An artificial grain is given by clay starch, &c.

Two kinds of genuine soft-soaps occur in commerce, whose composition is:—

	I.	II.
	per cent.	per cent.
Water	50·5	31·5
Potash	9·5	11·5
Fatty acids	40·0	50·0

The question of admixtures with genuine soft-soap, after its fabrication has been completed, is one that demands the serious attention of both manufacturer and consumer. They may be divided into two classes: (1) those intended to increase the detersive power; and (2) those added solely to cheapen the product. To the latter, belong clay, starch, fecula, glue, and a number of other fraudulent admixtures, whose detection will be dealt with under the head of soap-analysis. The first class demands a few explanatory words, and contains chiefly two substances, rosin, and silicate of soda or potash; the manufacture of the latter, and their use in hard soaps, are described on pp. 1786–7. For soft-soap intended for household and laundry purposes, rosin may be substituted for part of the saponifiable material (to the extent of 10–15 per cent. upon the total oil used) without injury, and, in some cases, with actual benefit; in the same class of soaps, the addition of silicate (or carbonate) of potash or soda certainly increases the detersive power, especially where hard water is employed. Most of the soft-soaps made, however, are used by woollen manufacturers, for wool-washing, fulling, scouring, and sizing, and there is no doubt that the best soap for these purposes is a *genuine potash-oil-soap*. Experience has shown that the addition of rosin has an undesirable effect upon the fibre, and that the presence of soda in any form is absolutely injurious to it. Wool in its natural state is lubricated by "suint," which contains nearly 50 per cent. carbonate of potash, and scarcely a trace of soda; it is evident therefore that in discarding soda, and using potash, the manufacturer follows the teachings of nature. The use of silicate of potash is injurious, since it attacks the fibre of the wool, and in some cases by its decomposition, even deposits silica therein, greatly to the detriment of the ultimate fabric. So much injury has been done by the use of unsuitable soaps, that many woollen manufacturers have been driven to make their own, thereby, as they think, ensuring purity. This, however, is also a hazardous proceeding, and it would be really more to their interest to state their exact wants, and to pay a proper and fair price for a soap carefully made with all the appliances and knowledge of a large soap-factory, than to run the risk of using a product in which, from want of practice or knowledge, a serious oversight had occurred. The excessive desire for cheapness on the part of purchasers has done more than anything else to depreciate the quality of soft-soaps (and of others). Further general remarks on this subject, and upon the desirability of purchasers buying soaps whose composition is guaranteed by analysis, will be found on pp. 1793–4.

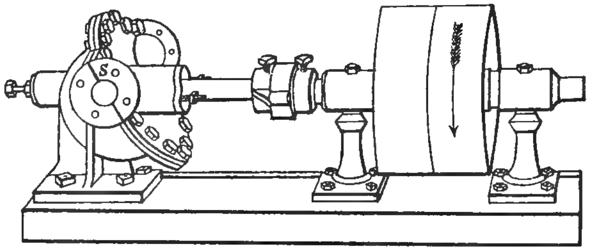
I, *c*, β.—The method of making "hydrated" soaps is very similar to that just described. Fatty matter and (soda) leys are run into the copper, and the whole is boiled together, care being taken to avoid an excess of alkali at first; when saponification has taken place, leys are cautiously added until the soap tastes very faintly of caustic alkali, when the operation is finished, and the soap is ready to be transferred to the frames. Marine soap, for use with sea-water, is made in this way, the fatty matter being entirely coco-nut-oil, and the leys being usually at 20° B. This soap is soluble in weak brine, which other soaps are not (p. 1769). It is difficult to make the saponification begin, but once begun, it proceeds with extraordinary rapidity, the united mass of oil and leys swelling up almost instantaneously to many times its volume. In connection with hydrated soaps, Blake and Maxwell give the following table for the quantity of soda leys necessary for their manufacture:—

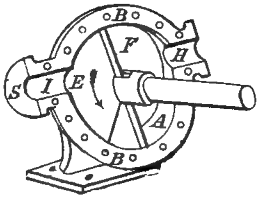
100 lb.	tallow	require	3800°	at	11° B.
„	coco-nut-oil	„	4100°	„	16°–20° B.
„	palm-oil	„	3200°	„	18°–22° B.
„	lard	„	3400°	„	13° B.
„	tallow oleine	„	2800°	„	18°–22° B.
„	olive-oil	„	3000°	„	16° B.

To use this table, divide the larger number of degrees by the smaller, and the quotient is the number of lb. of soda leys at the gravity of the divisor, required to make a hydrated soap with 100 lb. fat.

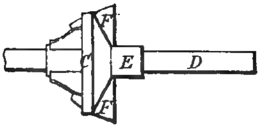
I, *c*, γ.—*Hard soaps*, with soda for a base, made by open-pan boiling, in which the glycerine is eliminated. This class probably includes 90 per cent. of the total soap made in English-speaking countries, and may be divided into three kinds, curd, mottled, and yellow. The coppers for their production have already been sufficiently described, but a necessary and hitherto unused adjunct must now be explained, viz. the pumps required for changing the leys beneath the soap. They may be placed inside the copper, or outside, and, in this latter case, are connected with the outlet pipes at K L, Fig. 1248. For small pans, a simple hand suction-pump answers; for larger ones, a single- or double-acting lift- or force-pump may be placed inside the copper, and worked by hand, or by an eccentric on a shaft. In large soap factories, some form of centrifugal pump will be found very useful; the usual objection to the use of these pumps, viz. the need of constant lubrication, being obviated by the fact that, so employed, they lubricate themselves. Their great advantages are the absence of valves and of easily deranged working parts, and the large amount of work they will do in a short time. In England, the names of Gwynne and Appold have long been connected with centrifugal pumps; in America, the one most usually employed is Hersey's patent rotary soap-pump (Hersey Bros., Boston, Mass.), which is represented in Figs. 1252, 1253, and 1254. The pump should be placed as little as possible above the outlets in the coppers, and connected therewith by $2\frac{1}{2}$-in. iron pipes, provided with valves. The pipes inside the copper, communicating with the outlets, have swing joints, so that they can be raised or lowered at pleasure. To avoid the pipe-system becoming choked by soap congealing in it, a steam-pipe should be inserted at one end, to warm the pipes and pump previous to use, and to "blow-out" all their contents at the end of the operation. In the figures, S is the suction-pipe; H, the delivery; F, the blades set upon a cone (the rotation of which in the closed case produces the pumping), which is kept in its place by adjustable set-screws. This pump will transfer to any desired part of the factory, leys, melted fat, finished soap (if not too stiff), "nigre," and soft curd. The diameter of the pump is 10 in., of its outlet $2\frac{1}{2}$ in.; when making 120 rev. a minute, it will pump 6000 gal. an hour, its contents being twice emptied in each revolution.

1252.





1253.



1254.

Whatever kind of hard soap is to be made, the first stages of the process are the same for all; but since a curd or a mottled soap requires the use of fire or "close" steam to evaporate water during the final stages, it is desirable to commence making those in coppers so provided, and either high-pressure or superheated steam may be used in the close-steam worm. Yellow soaps may be made in coppers furnished only with an "open" or "free" steam worm. A useful addition to any copper, giving more room to boil, and hence adding to its capacity, is a "curb," or ring 2–3 ft. high loosely fitted on in segments above the angle-iron of the top ring of the copper itself, and capable of easy removal. If, as in Fig. 1248, the copper project $2\frac{1}{2}$ ft. above the floor, a "curb" $2\frac{1}{4}$–3 ft. high may be conveniently added, and the fan adjusted so that its blades revolve about 1 ft. below the top of the curb.

To commence a boiling of hard soap, melted fat and caustic soda leys (hereafter only called leys) at about 11° B. are simultaneously run into the copper, and the steam is turned on; the same precautions to prevent an excess of leys must be observed as are detailed in making soft soap (p. 1776); if leys stronger than 12° B. be used at this early stage, saponification will not take place. When the contents of the copper present the appearance of a homogeneous magma or paste, leys of a higher sp. gr., say up to 25° B., may be cautiously added, but it is not essential to do so. The boiling, and the addition of fat and leys, must be continued until a small sample cooled between the fingers has a tolerably firm consistence, and when applied to the tongue, no caustic taste, or only a *very* faint one. Should there be a strong taste (or "touch," to use the American term), or should the sample separate into soap and liquor when squeezed, too much ley has been admitted, and more fat must be added. Should the sample be soft and greasy, more leys are required, especially if any unsaponified fat be visible; occasionally the two conditions obtain, both caustic liquor and fat appearing in a sample, which is evidence that combination has not taken place; the remedy is more boiling, with occasionally the addition of water. Practice alone will enable the operator to judge of the completion of this first operation, called "pasting" (French, *empâtage*). In English phraseology, it is called "killing the goods" or raw material, and the soap is then said to be "close" or in a "hitch" or "glue." In this condition, the soap should contain about $\frac{9}{10}$ of the total soda necessary for complete saponification, with a large excess of water, which is separated from it by the next operation.

Separation (French, *relargage*).—To effect this, a quantity of common salt is sprinkled into the copper while still boiling, or the strongest brine (24° B.) is run in. Since the quantity necessary depends entirely on (1) the sp. gr. of leys used in the last operation, (2) the amount of condensed water where free steam is used for boiling, and (3) whether there is much coco-nut- or palm-kernel-oil in the fat employed (p. 1769), no directions can be given as to how much salt should be added; the addition should be made cautiously and gradually (taking care to allow time for the solution of the salt), and continued until a small sample removed upon a spatula or trowel allows *clear* liquor to run from it. During this operation of "graining," the contents of the copper are very apt to boil unsteadily, and occasionally to boil over with great violence. When this point is reached, the whole process should be stopped, and, the steam being turned off, the copper should stand at least 2–3 hours. Its contents then divide themselves into two portions, the upper consisting of soap-paste holding about 40 per cent. water, and the lower of a solution known as "spent leys," containing common salt, any carbonate and other soda salts present in the original leys as impurities, and nearly all the glycerine of the fat employed (see p. 1800). It should contain *no caustic soda*, and *no soap* or saponifiable material; if it contains the latter, enough salt has not been used. For the presence of caustic soda, a sensitive tongue will be found a sufficiently delicate test, while the addition of a mineral acid will throw up a scum of fatty matter, if any be present; it will also be found useful to observe the sp. gr. of the spent leys, as a means of controlling the amount of salt used. After the copper has stood for some hours, the spent leys should be pumped off, and, if there is then sufficient room, more fat may be run in, and the whole operation repeated; at this stage, the rosin is usually added for a yellow-soap, being broken into lumps, and shovelled in, unless it is combined with soda in a separate copper, and mixed with the fat-soap on the next operation.

Clear-boiling (French, *coction*).—All the goods having been "killed," and the spent leys removed, a small charge of leys at about 12°–14° B. is run in, and the copper boiled for 2–3 hours; at the end of this operation, the soap should have a faint but decided caustic taste, and a small sample on a spatula should allow clear leys to run off it; if this be not the case, more, and in some cases stronger leys, must be added. This operation communicates additional soda to the soap, and washes out, as it were, some of the salt entangled in it. After some hours' subsidence, the "half-spent" leys that sink to the bottom are pumped off, and may be used in another copper for "killing" more fresh goods; the soap from such leys, however, will be of an inferior colour.

The next stage of this operation is to boil the copper with open steam; if the contents are not perfectly homogeneous, and in a state resembling a stiff paste, i. e. if the copper be not "close," but have a tendency to separate into leys and soap, when examined on a spatula, the sp. gr. of the entangled leys is reduced by the addition of water, until the desired condition is reached. A small stream of leys at about 12° B. is then allowed to trickle in, until the homogeneous paste again separates into flakes of soap and clear leys, boiling being continued all the time; the soap should now taste strongly of caustic soda, and feel hard when cold; this operation is technically called "making" the soap, and when enough leys have been run in, boiling should be continued for some hours, to ensure complete saponification, since it is difficult to make neutral fats take up the last portions of soda. The large coppers previously alluded to require a whole day (12 hours) for this operation.

The operations above described, may *in experienced hands* be somewhat reduced in number and time, but much greater care is then required. By the proper use of leys of various strengths, and of salt, it is possible to "kill" 40–50 tons of mixed tallow and rosin in one copper in a day—to dispense with the next operation—and to "make" the copper on the day following, finishing it on the third day. The mode of finishing depends entirely on the kind of soap required.

Curd Soaps.—The raw materials for curd soaps should contain no rosin, and but little, if any, coco-nut- or palm-kernel-oil, but any other oils or fats may be used. White curd is usually made from tallow or lard, or a mixture thereof; brown curd, from bleached palm-oil, or kitchen-grease, or bone-tallow; and manufacturers' curd-soaps, from various fats. When the soap is "made," the open steam is shut off, and the boiling is continued either with fire or with close-steam; this concentrates the leys, and the flakes of soap gradually approach the spherical form. From time to time, the boiling is stopped, the sp. gr. of the leys is observed, and a sample of the soap, from which the leys have been allowed to separate, is put out to cool. When it is sufficiently hard, the boiling is finally stopped, and after a few hours' subsidence, the soap is ready to be removed; the amount of water left in it varies inversely as the sp. gr. of the leys in which it is boiled.

Mottled Soaps.—The term is here used to denote the old-fashioned curd-mottled soaps, not those marbled with blue, grey, or red, which have appeared in the English and foreign markets within the last 20 years, and which are described on p. 1787. In the fabrication of soap, it is impossible to avoid entirely the presence of earths and metallic oxides. These consequently decompose a small portion of the soap, combining with its fatty acids, and forming soaps of lime, magnesia, and iron (from the "coppers"), which are insoluble, but softened by heat, and disseminated in a state of minute division through the soap-paste; any slight impurities in the fat employed, when not dissolved in the caustic soda solution, are similarly diffused. If, after a soap is "made," the leys in which it is suspended are concentrated to a point short of that necessary to produce hard curd-soap, and it is then transferred to the cooling-frames, with a certain quantity of leys entangled in it, these insoluble particles will, during the solidification of the soap, collect together, and produce the appearance known as "mottling." No rule can be given for the point of concentration; it varies with the fat used, with the amount of leys in the copper, with the quantity of salts other than caustic soda in them; and in short, the proper "mottling condition" is a physical one, chemical tests being of no use in deciding it. Nothing but practice and careful observation can make a successful mottled-soap boiler. The principle of the process has been clearly laid down, and the various formulæ given in books, involving in many instances several changes of leys, are but different modes of arriving at the same result, viz. the suspension of pure soap, and of soaps of the metallic oxides, in soda leys of a given sp. gr. If the soap be boiled too long, it "sets" in cooling before the mottling has had time to aggregate; if it is not boiled enough, an undue quantity of leys remain in the soap; but, from their mode of manufacture, mottled-soaps always must contain some leys in the cavities between the curds; hence they are the most suitable and really economical soaps for hard waters. It not unfrequently happens that the copper does not contain enough metallic soaps, &c., to produce a definite mottle. In this case, some "mottling" is added; for a grey, Frankfort-black, or very finely levigated black oxide of manganese, may be used; the peculiar greenish mottle which becomes red on exposure, characteristic of Marseilles and Castille soaps, is produced by adding some solution of protosulphate of iron to the copper when it is nearly finished (about 4 oz. of the salt to 100 lb. fat); the precipitated protoxide of iron suspended in the soap is greenish, but becomes peroxide in contact with air, to which the change to a red colour on exposure is due.

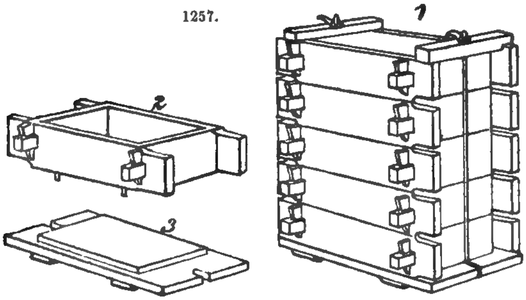
In England, mottled soaps are usually made from kitchen-grease and from bleached palm-oil. In Marseilles, from mixtures of various seed-oils, of which olive-oil is the principal, and cotton-seed-, poppy-, hempseed-, gingelly-, and ground-nut-oils are frequent components. In these mottled soaps, little or no coco-nut- or palm-kernel-oil should be used, although such oils form an almost essential constituent of the new mottled soaps referred to above.

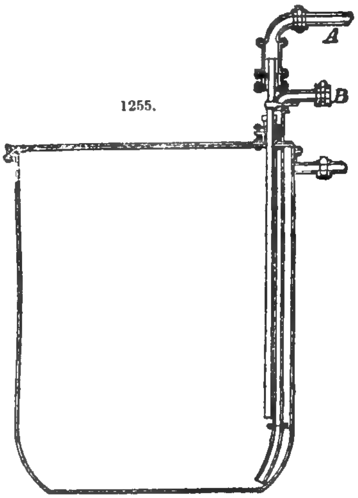
Yellow Soaps.—The finishing operation for these is termed "fitting" in England, and *liquidation* in France, and requires considerable judgment on the part of the operator. After being thoroughly well "made," the copper stands at rest for at least 12 hours; the half-spent leys are then pumped off, and the open steam is turned on. When the copper is again boiling, it should be continued so until its contents are perfectly homogeneous (the time depending much on the size of the copper), and the soap should then be examined with a clean trowel. When in proper condition, a thin layer should drop off a *hot* trowel held edgeways, in two or three flakes, leaving the metallic surface quite clean; but if, as is more probable, the layer breaks up into several small flakes, and the soap is stiff, water should be cautiously added, to reduce the sp. gr. of the still-entangled leys. If, on the other hand, the film will not leave the trowel at all, a small quantity of strong leys (say 15°–20° B.), or of brine, may be cautiously added, to cause it to do so. In the first case, the "fit" is said to be "open" or "coarse"; and in the second, to be "close" or "fine." Here, again, practice and observation alone enable the operator to obtain "a good fit," and when it is obtained, the steam is turned off, and the whole is allowed to stand. The copper is then covered up with planks, or an iron cover, and kept as warm as possible; small coppers may stand a day or two, large ones as long as a week. During this period, the contents arrange themselves in three layers, (1) a light crust full of air bubbles, technically called "fob," (2) the finished or "neat" soap, forming about $\frac{4}{5}$ of the whole, (3) the "nigre," which is an impure solution of soap in leys, and contains all the impurities present in the copper. The size of this last depends entirely upon the character of the "fit." A fine fit gives a very large nigre, containing much soap; while a coarse fit gives a small nigre, composed chiefly of impure leys. The English practice is to fit rather "fine," competition among the various makers for purity and colour being excessive; while the Americans are usually content with a coarse fit.

The finest yellow soaps are made from the best tallow and rosin, which last is an essential constituent of them; in some cases, lard, or lard-stearine, is used. Inferior qualities may be made from the nigres of better sorts, from bleached palm-oil, greases of all kinds, and in fact any saponifiable solid fat; fluid oils must be used, if at all, in small quantities and with caution. The proportion of rosin may vary from $\frac{1}{6}$–$\frac{1}{5}$ of the total fat, to an equal weight, or even more, according to the quality of soap required. In England, the very best quality is known in the trade as "primrose," and is made from the finest (unbleached) tallow and "window-glass" rosin; the lowest grade of brown from the nigres of the grades above, mixed with curriers' grease, leather tallow ("sod-oils"), and other dark and foul but hard fats, with black rosin.

The soap having been finished in the copper, the next stage is to transfer it to the cooling-boxes, or "frames," as they are usually called. Curd soaps should always be carefully skimmed off the leys by ladles, since they are too stiff to pump, and most mottled soaps are in this condition also; if, however, much leys be entangled in them, and the curd be flat, they may be pumped out. In large factories, fitted soaps are invariably transferred to the frames by suitable pumping machinery. A peculiar method of emptying coppers that contain perfectly homogeneous soaps, without any nigre or leys beneath them, was invented by Gossage, and is represented in Figs. 1255–6.

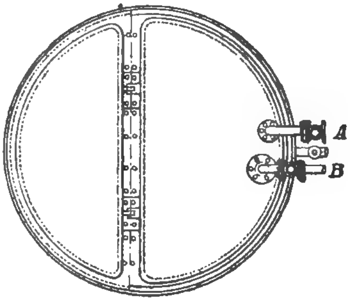
1257.





1255.

An air-tight cover is screwed on to the copper, and a blast of air is turned in through A; the pressure thus exerted forces the soap out through the delivery-pipe B in a continuous stream, until the lower end of that pipe becomes uncovered, when air rushes through it. This is chiefly used for the "blue-mottled" soaps, described on pp. 1787–8.



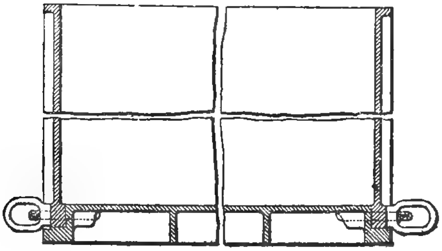
1256.

Soap-frames are of two kinds, according as it is desired to cool the soap slowly or quickly. In England, the internal measure of both is 45 in. × 15 in., a relic of the days when a duty (removed in 1853) was levied; the width of this makes the length of the English bar of hard soap. Where slow cooling is required, as is always the case with mottled soap, wooden frames, usually made of pine, are always employed. Their general appearance is shown in Fig. 1257; each section or "lift" (2) is lined with thin sheet-iron, the wood being 2½–3 in. thick, and the several sections, each about 9–12 in. deep, should fit closely upon each other when piled in a series (1). The bottom of the frame (3) may be made of wood or of brick; in the case of curd-mottled soaps, it is convenient to have a well in the bottom, to receive the leys which drain from the soap, especially if, as is frequently the case, the frame is 20–30 ft. high. Most curd and all yellow soaps are cooled rapidly in cast-iron frames of any desired shape and size. Figs. 1258–9 show a longitudinal section and plan of a form frequently adopted in England, which is almost water-tight; the superficial measure is 45 in. × 15 in., and the height 50–60 in. The four sides are held together by bolts and nuts, and when the soap is cold (i. e. after the lapse of 3–7 days for this size), these are unscrewed, the sides are removed, and a solid block of soap is left standing on the bottom of the frame. This may be at once cut up into slabs and bars, or may be slid away bodily to store. Occasionally such frames are mounted upon wheels, for convenience of transport about the factory.

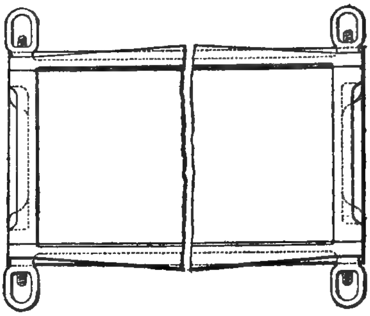
When it is desired to cut the soap, the sides of the block are marked with a scribe, Fig. 1260, the teeth of which are set at the thickness desired for the bar of soap. A brass or steel wire is then taken by two men, and drawn through the block, Fig. 1261, which is thus divided into slabs; these are at once removed to a machine which will divide them into bars. The cutting-machine usually employed in England is shown in Figs. 1262–4. The cutter itself is worked by a lever-frame L, which contains wires, or, for very hard soaps, thin steel knives *k*; the slab is placed longitudinally and nearly upright on the base-board *b*, and the lever-frame is then drawn through it.

The bars thus formed fall back upon the shelf *f* behind, whence they may be removed and set aside to get cold. Before repeating the operation, the lever-frame must be raised and hitched in its place by the spring-catch *c*. The bars, when removed from the machine, are piled across each other in "open pile," in such a way that air freely circulates among them. When thoroughly set, they are stored away in "close pile," or packed. In America, Ralston's cutter and spreader, Fig. 1265, is largely used; it has an arrangement A B for spreading and stamping the bars, and is very useful where soap is rather soft when freshly cut. The slab is laid upon C, and the cutting-wires are shown at D. Van Haagen, of Cincinnati, has devised a machine for dividing a frame of soap into bars all at one operation, and various slabbing-machines have been invented, none of which, however, has come into very general use, and they will not be further described.

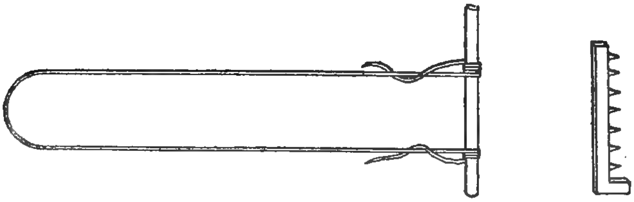
1258.



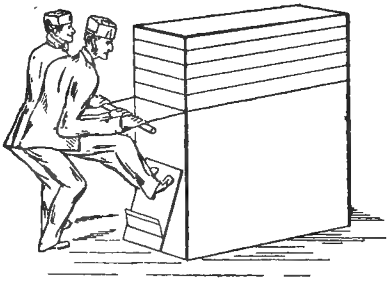
1259.



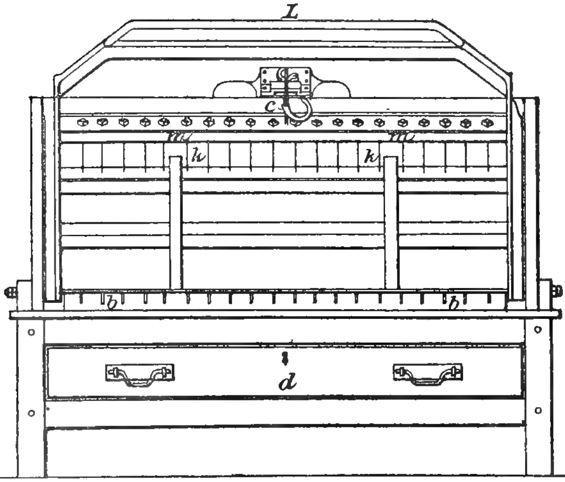
1260.



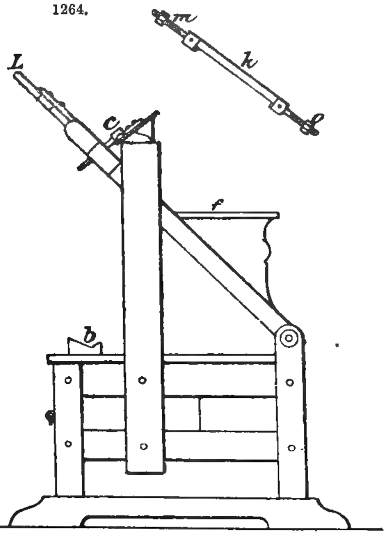
1261.



1262.



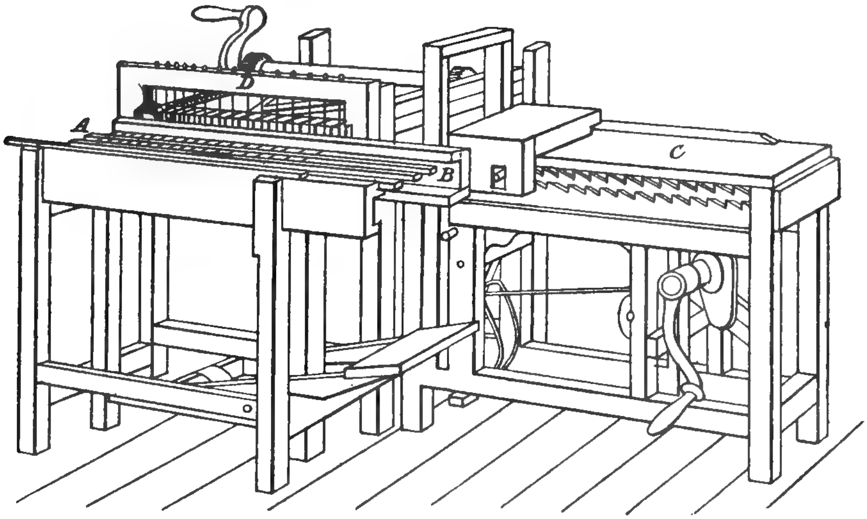
1264.



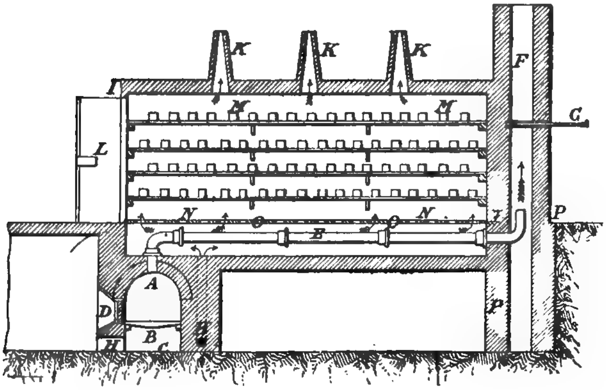
1263.

In connection with the cutting up of soap, it may be conveniently mentioned here that certain soaps undergo a kind of case-hardening process as soon as they have been barred-up. Most of the French mottled soaps are soaked, or even stored, in weak leys, or weak brine, or a mixture of both; and some of the English blue-mottled soaps are also soaked in brine. The usual process, however, is a drying one, which may be carried out either by directing a current of warm, dry air, by a fan or otherwise, against a pile of bars, or by spreading the bars in a drying-chamber, Fig. 1266, which is heated by fire to a temperature short of that at which the soap begins to melt. The fire is kindled in A, and the heated products of combustion pass along E to F, while the air, which enters at H, heated by them rises through the vent-holes O, and, after taking up much moisture from the soap M, passes out through K.

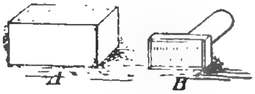
1265.



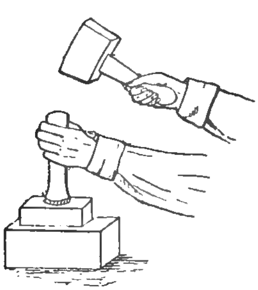
1266.



1267.



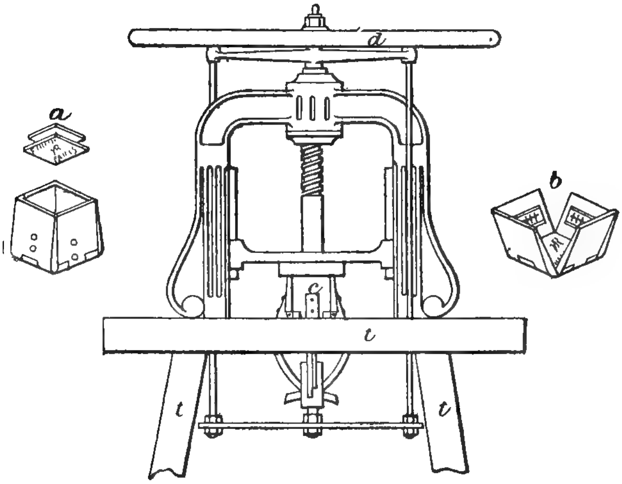
1268.



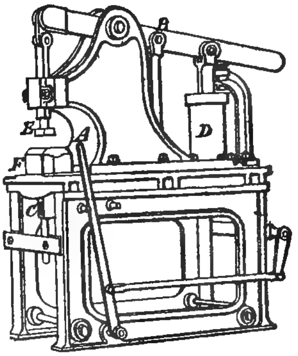
The bars of soap, when freshly cut and still soft, are usually impressed with some words indicating the name or quality of the soap, and the trade-mark or name of the manufacturer. This is most simply done by a hand-stamp, in which the letters or device are cut in hard wood or cast in brass (B); the arrangement and mode of using it with very hard soaps are shown in Figs. 1267–8.

In England, it has long been customary to sell soap in bars 15 in. long, weighing 2½–3 lb.; but during the last 5–6 years a great demand has sprung up among the retailers for ordinary household soaps cut and stamped into 1-lb., ½-lb., and ¼-lb. blocks, a form which also obtains to a very large extent in America. Various parts of each country differ considerably in the shapes preferred for these blocks, and the formation of each kind demands a special set of cutting-wires and of moulds and dies for their production. The 1-lb. and ½-lb. blocks are often "semi-cut," so that they can be readily divided into two ½-lb. and ¼-lb. pieces respectively. The simplest moulds are usually cast in brass, each tablet requiring two, producing an upper and an under surface; but occasionally a

1269.

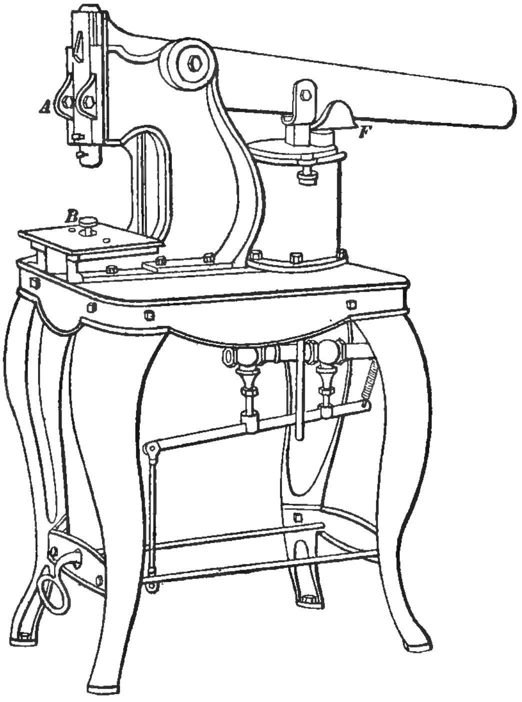


1270.



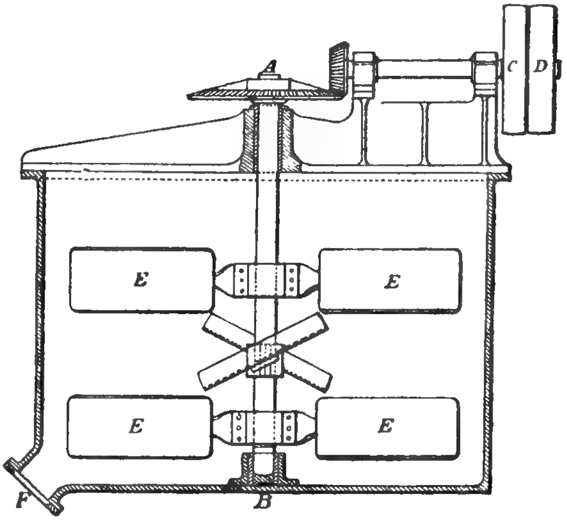
mould-box *a b* with hinged sides is employed, with a screw-press, such as is represented in Fig. 1269. With the ordinary tablets, it is necessary to slightly dry them superficially, and to give them a *very* thin coating of oil, that they may not stick to the die. The simplest form of hand-press will stamp upwards of 600 ¼-lb. pieces an hour. For larger tablets, a foot-power press is desirable, such as that made by W. H. King, Philadelphia. All large manufacturers, however, employ some form of steam-power press; one made by Neill & Sons, St. Helens, Lancashire, England, is shown in Fig. 1270. By moving the handle A, steam is admitted into the bottom of the steam-cylinder D; the piston being forced up the cylinder lowers the die E into the die-box F. The rod attached to the lever at B works in connection with a die that is always in the die-box and attached to the spindle C, having a slot for the lever to work in such a manner that when the piston is at the bottom of the steam-cylinder the bottom die is at the top of the die-box, and when the piston is at the top of the cylinder the bottom die is at the bottom of the die-box; thus the stamped tablet, being raised out of the die-box at each stroke, can readily be removed. The great advantage of the lever working the steam valve is, that the attendant must take his hand from the dies before the blow is given, thus preventing accidents arising through the blow being given when the hands are at the dies. Another form (Fig. 1271) is made by Hersey Bros., Boston, and with it a smart workman can mould 2000 cakes an hour; it is supplied with steam at 20 lb. pressure through a tin pipe.

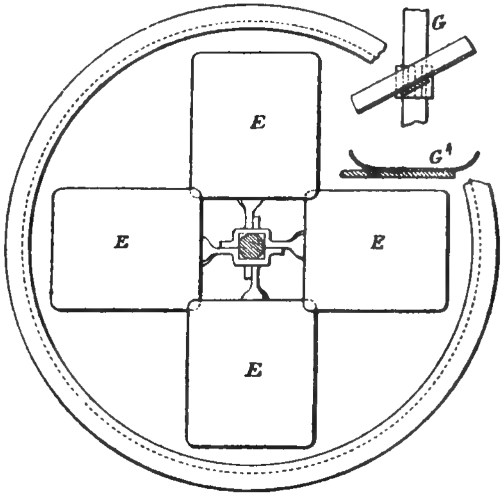
1271.



Hitherto, in treating of the fabrication of soap, genuine, unsophisticated, or "neat" soaps, containing not more than 32 per cent. of water when freshly made, have been described. It now remains to deal with the various substances which are mixed with soaps after they have been removed from the copper, by almost every manufacturer, and the mode of their incorporation, known in the trade by the suggestive name of "filling." These may be classed under two heads. The first class, which will be considered somewhat in detail, comprises all those soluble alkaline salts, such as silicates and carbonates, added to soap to increase its detergent power; between the two classes may be placed water, which is always present to a greater or less extent in "filled" soaps, and simply reduces their actual value and economical use; while the second class includes *all insoluble substances*, such as clay, steatite (i. e. soapstone, or magnesian silicate), powdered talc, sulphate of baryta, starch, fecula, and all soluble substances, such as glue and gelatine, which have *no detergent power* in themselves, and are simply added to increase the quantity of water in soaps, or as mere adulterants or make-weights. (A notable example of this is the use of clay or steatite, 5 or even 10 per cent. of which may be mixed with soap without its presence being apparent to the eye.) For obvious reasons, only the use of the first class will be described in the present article; but further remarks on the subject, and methods for detecting and determining the quantity of these adulterants, will be given under the head of Analysis of Soap, pp. 1794–6.

1272.





1273.

With the exception of the silicated mottled (blue, grey, and red) soaps, a special description of which will be given, all "filled" soaps are made by incorporating the soap-paste fresh from the copper with the "filling," at a temperature of about 77° (170° F.). On a small scale, this may be readily done by stirring the two together in the soap-frame with a "crutch," which is a perforated piece of wood or iron, whose flat side is attached at right angles to a pole, by which it is moved by a man vertically up and down in the frame. When many tons have to be mixed, however, machinery in some form must be employed, and the choice of the form thereof depends upon the probable consistency of the mixture. Whatever form be decided upon, it is quite essential that it should not merely mix the soap in one plane, but that the contents of various planes should be intermingled; simple rotation of arms at right angles to a vertical shaft is therefore insufficient.

Such an arrangement is shown in Figs. 1272–3. The blades E of the mixers are set at an angle of 45° on the shaft A B, at the top of which is a pair of bevel-wheels, with fast and loose pulleys C D; F is the discharge-hole, provided with a valve for drawing off the stiff soap. At G G', are portions of the mixers and scrapers in section. It is desirable, but not necessary, that there should be some means of controlling the temperature of the tanks or vessels in which the "crutching" (as this mixing process is technically called) is carried on. Close steam-worms or steam-jackets are very suitable for this purpose; they should in all cases, however, be cased with a non-conductor, to prevent loss of heat by radiation.

Where very stiff soap has to be crutched, probably the best arrangement is an archimedean screw, which is very largely used in America, where most of the soap made is very stiff; this lifts up the various layers most effectually, and is most conveniently set inside a jacketted cylinder, whose height is about 1½ times its diameter. For crutching soaps that are somewhat thinner, such as are usually made in England, the crutching-machinery designed by Neill & Sons, St. Helens, Lancashire, is very suitable.

One of the earliest methods of cheapening, hardening, and increasing the detersive powers of soaps was that proposed by Dr. Normandy, who mixed "neat" soap with crystallized sulphate of soda, previously melted in its own water of crystallization. The salt re-crystallized in the soap as it cooled, and the soap was thereby considerably hardened, so that it wore better in the wash-tub when rubbed upon clothes, and in this way its detersive power was mechanically increased, although sulphate of soda as such, being a neutral salt, had no detersive power of its own, and its addition to soap really diminished chemically the percentage of soda available for washing. These soaps usually effloresced with a white powder, and gradually fell out of use, especially as raw fatty matters became cheaper.

It was then discovered that the addition of carbonate of soda, or "sal soda," has a remarkable effect in stiffening and hardening soaps to which it is added in a state of strong solution; it also increases chemically its detergent power. This process is very largely employed in America; the amount of soda used depends upon the raw materials from which the soap was made, and upon the quality of the desired product; a very usual proportion is 1 cwt. carbonate of soda crystals (melted) to every ton of soap. Not unfrequently, a solution of pearl-ash (impure carbonate of potash) and common salt, mixed in varying proportions, at a sp. gr. of about 30–35° B., is used for a similar purpose.

Silicated Soaps.—The discovery of methods of manufacturing on a large scale soluble silicates of soda and potash, gave a very important impetus to the soap-trade, since these substances are peculiarly suitable for the purposes now being described. The first application on a large scale was the production of soaps by Christr. Thomas & Bros., of Broad Plain Soap and Candle Works, Bristol, containing both silicate and sulphate of soda, and by these means they were able to produce in 1856 a soap of very great detersive power, which could be sold retail at less than the duty on soap, which had been removed a few years previously. It is usually supposed, however, that the value of silicated soaps was first publicly and officially recognized at the International Exhibition of 1862, when a prize medal was awarded to W. Gossage and Sons, Widnes Soapery, for their samples.

It will be convenient, therefore, to describe here shortly the process of manufacture and properties of the silicates of soda and potash. These compounds, known also as soluble glass or water-glass, may be prepared either by the dry or wet methods. The first is usually adopted by Gossage, Crosfield, and others; it depends on the fact that, at high temperatures, silica plays the part of a very strong acid, capable of displacing acids much stronger than it at ordinary temperatures. On the clean hearth of a reverberatory furnace, 9 parts of soda-ash at 50 per cent. soda are fused with 11 parts clean white sand, or (for the potash salt) equal parts of carbonate of potash and sand. The product may be sold in the dry state, or may be dissolved in boiling water; not unfrequently boiling under pressure is necessary to effect complete solution. If the solution be too alkaline, it may be boiled with rosin, or a fatty acid, or it may be treated with a mineral acid, either liquid or gaseous. Instead of carbonate of potash, a mixture of "salt-cake" (sulphate of soda) and coal may be fused with sand, and the mixture decolorized by arseniate of soda (i. e. a mixture of white arsenic, nitrate of soda, and soda-ash), but a much higher temperature is required in this case, and the wear and tear of the furnace is very great.

For purposes where uniformity of composition is important, it is far better to employ the wet method, as is used by Ransome for artificial stone, and by Christr. Thomas & Bros., Bristol. In this case, white sand or calcined flint is put into a Papin's digester, with a solution of caustic soda at about 12° B. Steam is turned into the jacket, and maintained there at about 25–30 lb. a sq. in.; occasional samples are drawn off by a try-cock, and when all trace of causticity has disappeared, steam is turned off, and the contents are "blown out" into tanks where a few hours' subsidence deprives the solution of all suspended impurity. It is then about 24° B., and may be concentrated, if desired, as far as sp. gr. 1·700. Any mechanical arrangement that moves the flints about, facilitates their solution. Made in this way, the silica and the soda bear to each other a very simple, but a very constant, ratio, viz. 2 to 1, and hence great uniformity of composition is obtained, which is not always the case when soluble silicates are made in the furnace. The compound is usually sold in solution at 140° Tw. (sp. gr. 1·700), and should scarcely vary from this composition:—

Silica	33·00	per cent. to	32·00
Soda	16·50	„	16·00
Other soda salts	2·50	„	3·00
Water	48·00	„	49·00
	100·00		100·00

Solutions of silicate of soda, containing a larger proportion of silica than 2 to 1, cannot be concentrated so far, but are very suitable for many soaps; those containing less silica than 2 to 1 are unsuitable for all soaps, and should be carefully avoided.

Silicate of soda may be mixed with almost any kind of soap, but the strength of the solution employed must be varied according to circumstances. Very weak solutions are often added to "neat yellow soaps," and when employed in this way, it is a good general rule, *ceteris paribus*, to increase the sp. gr. of the solution with the percentage of it employed. Thus, if it be desired to increase the quantity of water in a "neat" soap by 4–5 per cent., a solution at 5° B. will be suitable; while if the quantity of water is to be increased to a total of 50 per cent., a stronger solution (10–12°) is required. This kind, technically known as "run soap," was at one time largely made in America, and still is in England under the name of "London pale." Such soaps are of the consistency of thin treacle when mixed, at say 160–170° F., and are apt to disappear rapidly in hot water, as well as to lose weight when kept.

A more legitimate application of silicate of soda is to mix varying quantities of the concentrated solution with "neat" yellow or curd soaps. This treatment makes yellow soaps much stiffer, and in many cases, by hardening them, adds to their durability. About 5 per cent. of the solution at 1·700 sp. gr. is a suitable quantity, and has much the same effect as the addition of 5 per cent. of carb. soda crystals before described. Much larger quantities than 5 per cent. may be used, but soap so treated is apt to disintegrate unpleasantly in the hands of the consumer. Curd soaps are sold in England with which 15 or even 20 per cent. of silicate of soda at 1·700 sp. gr. have been mixed. These large quantities considerably increase the "soda available for washing," as given by the alkalimetric test (see Soap Analysis, p. 1794).

Aluminate of soda.—As a detergent for mixing with soap, this substance is perhaps even more powerful than silicate of soda. It is chiefly obtained from cryolite, a mineral found in great abundance in Greenland, and may be readily prepared from it by boiling it with lime; cryolite, being a double fluoride of aluminium and sodium, gives up the whole of its fluorine to the lime, leaving a mixture, or compound, of alumina and soda. Like silicate of soda, it is not a definite chemical compound,—as will be seen by the following analyses of different samples:—

	A.	B.
Soda	43·0	44·0
Alumina	40·0	24·0
Water	9·0	32·0
	100·0	100·0

The commercial product is an amorphous white substance, readily soluble in water, in which state it may be mixed with soap, like silicate of soda.

Blue, Grey, and Red Mottled Soaps.—These come under the head of silicated soaps, and are thus made. Two coppers are required, an ordinary steam copper for the first stage, and a fire-copper for the later stages. In the steam-copper, the raw materials are killed, made, and fitted rather open. The fat-mixtures employed are usually vegetable oils, and almost always (though not necessarily) contain a fair proportion of coco-nut- or palm-kernel-oil. When first introduced from Germany, these soaps were made from well-bleached palm-oil and coco-nut-oil, in such proportions as 3 palm- to 2 coco-nut-, or 2 to 1, or even 3 to 1. Latterly, however, palm-kernel- has supplanted coco-nut-oil, and some of the palm- has been replaced by refined cotton-seed-oil. The choice of materials is very much guided by their cost. The fitted soap is shifted off its nigre into the fire-copper, and, to every 1000 lb. of it, is added about 250 lb. solution of silicate of soda at about 20° B.; the exact sp. gr. depends chiefly upon the proportion of palm-kernel- to other oils. The whole is then boiled together with steam and fire, to thoroughly incorporate the mass; when this is complete, the steam is stopped off, and the appearance of the copper is examined. Practice and experience, assisted by chemical analysis, can alone decide when the soap is in "mottling condition"; in that state, it should have about 45 per cent. (or less) fatty acids, and 0·5–1·0 per cent. of sodium chloride, according to the raw materials employed. A good physical test is to take a layer out rapidly upon a cold trowel, and observe its appearance, and the time required for it to "set." A shiny appearance on its surface indicates a deficiency, a frosty appearance, an excess, of mineral salts; if it sets too quickly, and is shiny, more sodium chloride must be added; if it appear frosty, and is long in setting, enough mineral salts are present. So delicate is the process, that the addition of 1 lb. salt to a ton of soap at this stage will entirely alter the appearance of the mottling when cold. When it is in mottling condition, the mineral substance used as mottling is mixed with a small quantity of water, and sprinkled into the copper; it is there thoroughly incorporated with the soap by a few minutes' boiling, and the soap is then transferred as rapidly as possible to *wooden* frames, which are carefully covered up when full, and kept as warm as possible, to allow time for the "mottle to strike." For blue mottle, 5–10 lb. artificial ultramarine per ton of soap are used; for grey, 1–3 lb. finely levigated oxide of manganese. If the soap be cooled rapidly, it will be of a homogeneous blue or grey colour; slow undisturbed cooling is essential to these soaps, and once in the frame, they should never be touched until they are quite cold; it was for them that Gossage devised the pneumatic method of emptying coppers (p. 1781), but a centrifugal pump answers as well. It requires greater skill to make good "blue-mottled" soap than for any other kind, and the manufacture is in the hands of a few large firms. It may be observed here that in these soaps, the mottling, so difficult to produce, is a matter of appearance merely, and that soap with a plain white ground would wash just as well.

Another mode of producing these soaps is to make a portion of the fat employed (usually all the coco-nut-oil, with or without some portion of the other oils) into hydrated soap (p. 1777); the remainder of the fatty matter is made either into a "fitted soap" or a "flat curd" soap, and then transferred to the hydrate previously prepared in another copper; after both are incorporated by thorough boiling, the soap is finished as before directed. This method, for which Blake & Maxwell and C. N. Kottula had various patents, was introduced into England from Germany by the last named about 25 years ago; it is said to produce a more solid and close soap from the same materials than any other method, but when a blue-mottled has to be made, the greatest care must be used to allow no impurities in the materials used for the hydrated soap, or the brilliancy of the blue mottling will be interfered with.

Manufacturers' Soaps.—The various kinds of household soaps having now been described, a few remarks will be made upon the soda-soaps suitable for various manufacturing purposes. Most of these are dissolved in water for use, and hence it is immaterial into what sized bar they are cut. Care, however, should be taken that they *are* dissolved; a case occurred in the writer's knowledge when the quality of a soap was much complained of, as producing greenish stains upon black cloth. The soap-maker asserted his ignorance of anything deleterious in the soap, and subsequent investigations showed that the cloth-manufacturer's workman, instead of completely dissolving the soap, had impregnated the cloth with a solution containing *undissolved pieces*, and the soda in these, not unnaturally, affected locally the indigo and logwood with which the cloth had been dyed.

For ordinary scouring purposes, there are few better soaps than the old-fashioned curd-mottled: many others, however, are used, such as curd soaps made from cheap and inferior greases, and boiled very dry; and fitted soaps from greases and black rosin. For scouring goods of finer quality, a white curd soap from tallow, or tallow and lard, is used, or a curd soap from olive- or cotton-seed-oils, or a mixture of both. The soaps made on Morfit's plan (p. 1771) are also good scouring soaps. As a rule, traces of unsaponified fat (or indeed any extraneous material) are very deleterious in manufacturers' soaps, which, under ordinary circumstances, should contain a very slight excess (as curd and mottled soaps always do) of caustic soda. When for any purpose, as e. g. where delicate dyes are employed, an absolutely neutral soap is required, either a "finely-fitted" soap should be used, or a curd soap from which the caustic leys have been pumped off, and the soap finished by boiling on brine.

According to Crace-Calvert, soaps for dyers' use are not indiscriminately applicable to all colours. To produce the maximum effect in brightening the shade, the soap should be:—

	For Madder Purples.	For Madder Pinks.
Fatty acids	64·4	59·23
Soda	5·6	6·77
Water	34·0	34·00

For some purposes, a soap that will remain liquid in solution at a low temperature is required; such soaps are well made by Morfit's process, and should contain large quantities of oleic acid. For "fulling," this soap is often employed, mixed with curd soap made from unbleached palm-oil only.

Much has been written about the frauds practised by unprincipled soap-makers upon manufacturers using soap, and the latter have been advised, in self-defence, to make their own soaps. Reasons have been given (p. 1777) against this course; it is much to be desired, however, that soap-*users* would take soap-*makers* personally more into their confidence in explaining their requirements, and would themselves superintend (and not leave to their foremen) any experiments made on the working of different kinds of soap. A system, too, on which manufacturers' soaps should be sold, guaranteed to contain a given percentage of fatty matter of a definite quality, with its full equivalent of soda, is greatly needed. Such arrangements, if carried out, would very probably put this trade upon a far better footing than it is at present.

Special Household and Laundry Soaps.—A few of these, including the commoner kind of scented soaps, will now be considered. Cheap toilet soaps are thus made on a large scale. For "honey" soap, a good "neat" yellow soap is taken, and a solution of some yellow dye is mixed with it; 5 per cent. carb. soda crystals, or 5 per cent. sil. soda at 1·700 sp. gr., is then added to stiffen it; the whole is crutched, and scented by the addition at as low a temperature as possible of as much citronella-oil as is deemed necessary. For "brown almond soap," an inferior grade of yellow soap is similarly treated, and scented with about 10 lb. to the ton of mirbane (i. e. nitro-benzol) or artificial almond-oil. When cold, these soaps are cut into bars or cakes, superficially dried, and stamped with one of the foot-power or steam stamping-machines (p. 1784).

Cold-water Soaps.—This term, which has made its appearance within the last 5–6 years, was at first confined to soaps made from very soft materials, but containing a very small amount of water; such, for instance, as those produced by Morfit's process. They are sold at a low rate, and, from their great dryness, may be kept indefinitely without losing weight, a property possessed by scarcely any other household soap; being perfectly pure soap, they are truly economical, provided they are not used with hot water. Christr. Thomas & Bros., of Bristol, and Sinclair, of London, have a great reputation for these soaps, which have been recently introduced. Latterly, however, the use of the term has been appropriated by makers of heavily-watered soaps, which run away in hot water.

Disinfecting Soaps.—In few ways can disinfectants be so agreeably applied to the skin as when incorporated with soap. One of the last introduced, though probably one of the most efficacious, is thymol soap—made solely by Ferris & Co., Bristol. Thymol is a non-poisonous (herein differing from carbolic acid) crystal, about 8 times as powerful an antiseptic and disinfectant as carbolic acid, and is probably the only substance that combines disinfecting properties with a really pleasant smell, that of thyme. The mode of incorporating thymol and phenol (i. e. carbolic acid) with soap is a trade secret; Morfit states that carbolic soaps are best made by his process (p. 1771), using as a basis hot-pressed fat-acid cake, on account of the tendency of carbolic acid to soften the soap-paste.

Carbolic soaps are made in great variety and in large quantities by F. C. Calvert & Co., of Manchester, whose products contain definite specified quantities of carbolic acid of various qualities. Their "medical" soap contains 20 per cent. pure crystal; their toilet and household soaps, 10 per cent.; their domestic soap, 8 per cent.; and their "No. 5" or "scouring" soap, 4 per cent. liquid carbolic and cresylic acids. The comparative antiseptic power of soaps may be tested by adding equal weights, in solution, to equal weights of flour-paste, and, after exposing these to the air under identical conditions, noting the day on which mould first appears on each. The so-called "coal-tar" soap or "sapo carbonis detergens," owes its disinfecting properties to a small quantity of carbolic acid in the coal-tar.

Sand Soap.—Under this heading, occur a number of soaps in which it is sought to unite the chemical power of soap with the mechanical aid afforded by sand in scouring. As much as 20 per cent. of clean sand or powdered quartz is sometimes mixed with soap-paste. In a similar way, soap is made the vehicle of many substances to be applied to the skin, medicinally or otherwise, or in any cleansing process. All these should be incorporated with "neat" soaps, freshly made or remelted, at as low a temperature as possible. Some form of soap is not unfrequently the basis of polishing pastes.

Fine Toilet Soaps.—Three distinct processes are in vogue for the fabrication of these, according to the quality of the product desired. For the commoner kinds, the basis is a good grade of fitted yellow soap, taken direct from the copper, or remelted in a small steam-jacketted pan, or in a Whitaker re-melter, provided with continuous coils of steam-pipe. To this, are added (1) suitable colouring matter, in a soluble form if possible, such as some aniline dye, (2) some mineral salts, as carbonate of soda or potash, salts of tartar, &c., to stiffen and "close" the soap, usually about 5 per cent. in strong solution, (3) at as low a temperature as possible, the perfume. When cold, the soap is cut up into slabs, bars, and cakes, dried, and stamped, as previously described. A few formulæ for perfumes are here given, calculated in each case for 100 lb. soap:—

Brown Windsor.—4 oz. oil of cinnamon,
1 ,, ,, cloves,
1 ,, ,, caraway,
2 ,, ,, sassafras,
2 ,, ,, bergamot.
Or – 4 oz. oil of bergamot,
2 ,, ,, caraway,
2 ,, ,, cassia,
8 ,, ,, lavender,
1 ,, ,, cloves,
1 ,, ,, petit-grain.

Almond Soap.—12 oz. oil of bitter almonds,
4 ,, ,, lemon.
Honey Soap.— 8 oz. oil of citronella,
2 ,, ,, lemon-grass.
Glycerine Soap.— 2 oz. oil of cassia,
1 ,, ,, caraway,
4 ,, ,, lavender,
1 ,, ,, mirbane.

In connection with "Brown Windsor" soap, it may be mentioned that the more it is melted, cooled, manipulated, and remelted, the better it becomes, and that the scraps of various sorts of soap that accumulate in the factory are usually worked into this soap.

The intermediate quality of toilet soaps are made by the cold process (pp. 1771–2), from the purest materials that can be prepared, and when the fatty matter (tallow, lard, &c., with occasional coco-nut-oil) and leys have been well stirred together, the colouring matter, perfume, &c., are added, and the whole is left quiet to effect the saponification. As previously directed, the fat should not exceed 49° (120° F.), and ½ its weight of caustic soda leys at 36° B., should be stirred into it; in about 5 hours, when saponification occurs, the temperature will rise to 82·2° (180° F.). This method enables more delicate perfumes to be used, since they are added at so low a temperature. A marbled appearance may readily be given to this soap by drawing, in wavy lines through the mixed fatty matter and leys, a steel blade dipped in colour ground up with oil; to produce a good effect, the peculiar wrist-turn should be used with the blade, such as is required to wield a fencing foil well. It is obvious that these soaps retain their own glycerine.

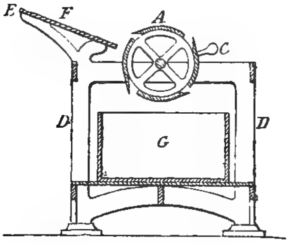
To the perfume formulæ given above, may now be added:—

Rose Soap.—4 oz. oil of rose geranium,
2 „ „ bergamot,
1 „ „ rose,
1 „ „ cinnamon.

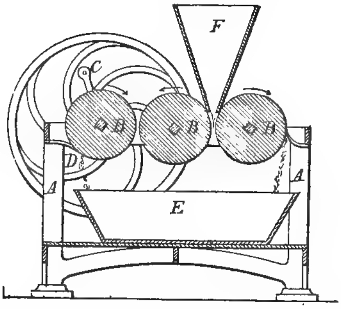
Marsh-mallow Soap.—6 oz. oil of lavender,
4 „ „ lemon-grass.
½ „ „ peppermint,
½ „ „ petit-grain.

The finest qualities of toilet soaps, however, require a great deal of manipulation by costly machinery, which has been chiefly devised by the French, although the Americans, with their well-known mechanical ingenuity, have recently constructed equally good machines. The basis of these soaps, or "stock" as it is technically termed, is usually made by the cold process, from the purest possible tallow, lard, &c., with little if any coco-nut-oil, which, if used, should be the Cochin variety. All the colouring matter, perfume, and other ingredients, are incorporated with the soap under hydraulic pressure, at the ordinary atmospheric temperature; hence the most delicate essences can be employed, even those that are extracted in the cold from plants. The first operation is to "strip" the stock-soap, i. e. to cut it up into strips or shavings; this may be done with a plane by hand, or by a machine (Fig. 1274), whose essential parts are a revolving wheel A, upon which are set 4 or 6 knives, and a hopper F to contain the bars. After stripping, the soap is frequently dried somewhat, and it is then passed through the mill several times, while the colour, perfume, &c., are here added to it. The mill, which is shown in Figs. 1275–6, consists essentially of three cylindrical contiguous rollers B, by whose action the soaps, colour, perfume, &c., after repeatedly running through, are blended into a thick homogeneous paste. When this has been effected, the soap is ready for the final operation, known as "plotting" (from the French, *pelotage*), in which the paste is subjected to enormous pressure, sometimes 3000–4000 lb. a sq. in., to form it into cakes, or into continuous bars from which cakes may be cut. Such a machine, known as Rutschman's hydraulic soap-plotting machine, made in Philadelphia, is shown in Fig. 1277. It may be charged 5 times in

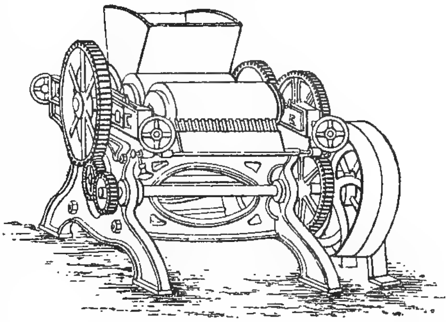
1274.



1275.

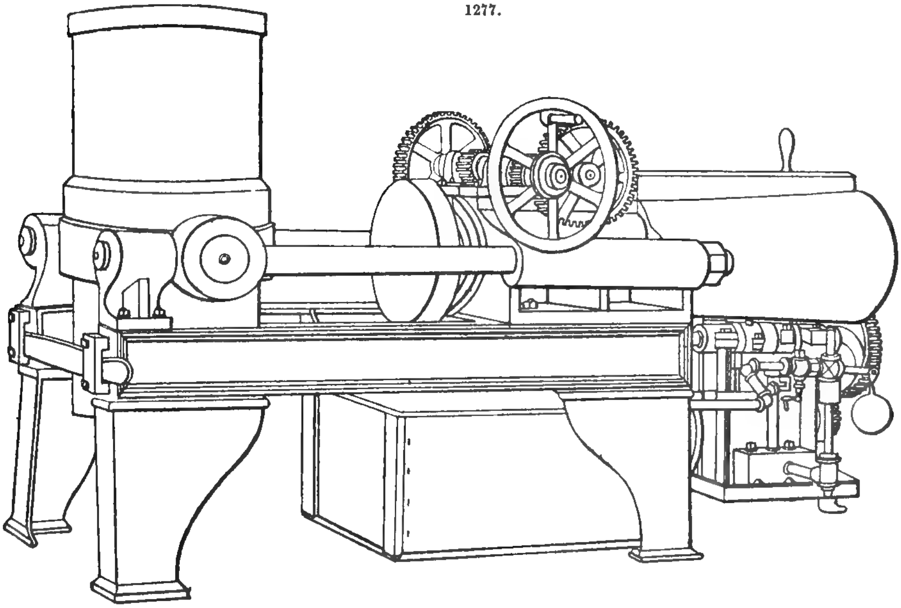


1276.



a working day, and will "plot" 200 lb. at each operation. It is better to let each separate cake be "plotted" by this machine, but if bars are made, and the cakes subsequently stamped, a powerful stamping-press must be employed. Cakes made in this way, are not liable to crack in use, as those made by the other two processes are; before being packed, they are not unfrequently dried, and almost always polished. This may be done by hand with a cloth moistened with alcohol, or, according to Dupuis, by momentary exposure to a current of steam, which, if desired, may be previously passed through a cloth impregnated with any fragrant odour; it is said that no other method gives such a beautiful, even, and lustrous coating.

1277.



A few hints on colour, and formulæ for perfume, are here given. Whenever it is desired to produce a mottled or marbled appearance in the soap, an insoluble colour must be employed; but whenever a uniform tint is required, preference should be given, whenever possible, to colours soluble in either water or alcohol, a condition fulfilled by numerous coal-tar colours. Care should be taken to choose those that are permanent, and unaffected by strong alkali. Salts of chromic acid should be avoided, since they are apt to turn green by transference of some of their oxygen to the fatty matter of the soap; the borate of chromium, known as "Guignet's green," is very stable, and so are ultramarine and vermilion. The finest yellow is produced by infusion of saffron. The resources of the dyer's art are constantly producing new tints, whose properties in relation to soap must be ascertained by that best of all tests, experiment.

The following recipes for high-class toilet soaps may be found useful; the quantities are calculated for 100 lb. soap:—

Orange Soap.

	oz.
Oil of orange peel	8½
" cinnamon	½
" thyme	2

Lemon Soap.

Oil of lemon	8½
" bergamot	4
" lemon-grass	4½
" cloves	2

Elder-flower Soap.

	oz.
Oil of bergamot	8½
" lavender	2
Oil of thyme	2
" cloves	1
" cassia	½
" almonds	½

Millefleur Soap.

Oil of orange (Portugal)	10½
" lavender	5
" cloves	2½
" nutmegs	5
Tincture of musk	5

N.B. Impregnate the fats used in this, with vanilla, ambergris, and rose-leaf.

Violet Soap.

	oz.
Powdered orris root	71½
Oil of lemon	5
„ rhodium	2½
„ thyme	2½
Tincture of musk	5

Finest Honey Soap.

Oil of citronella	8
„ lemon-grass	4
„ cassia	2

Rose Soap.

	oz.
Oil of rose	2½
„ rose-geranium	2¼
„ cinnamon	1
Oil of bergamot	1¼
Tincture of ambergris	½

Glycerine Soap.

I. Oil of lavender	4
„ bergamot	2½
„ thyme	1¼
„ cloves	1
„ carraway	¾
II. Oil of rosemary	6
„ orange	3
„ cassia	1
„ thyme	1
„ mirbane	1

Transparent Soaps.—The peculiar appearance of these soaps is due to the use of alcohol in their fabrication, and it may be applied in two ways. The older method, still employed, is to cut up ordinary soap into shavings, to dry these in heated air, and to dissolve them in half their weight of alcohol of 95°, in a suitable closed vessel provided with a head and condensing-worm, and heated by steam or a water-bath; when the soap is dissolved, and the excess of alcohol evaporated, the soap is drawn off, perfumed, and allowed to cool. Transparent soaps are now, however, usually made by the cold process, but to ensure success, very great exactitude in the proportions of the materials used is necessary, as well as much experience and skill. The fatty matters employed are tallow, coco-nut-oil, lard, castor-oil, and olive-oil, in varying proportions, but all of the purest quality. For 100 parts by weight of fatty matter, 45 parts caustic soda leys at 40° B., and 50–55 parts of alcohol of 95° should be used. One half the leys should be stirred into the melted fat, the temperature of the mixture not exceeding 49° (120° F.), and when thoroughly incorporated the remainder of the leys, mixed with the alcohol, should be added; saponification will take place rapidly, and the perfume should now be added, and the whole cooled very gradually in frames; 20 parts glycerine added to the above will make a good transparent glycerine-soap; occasionally some clear syrup of white sugar is added also. These soaps are seldom coloured, but any colour used in them should be quite transparent; it will be noticed that they do not become quite transparent until they have been exposed to the air for some days.

Solidified Glycerine.—The preparation of this by Price's Candle Co. is a trade secret, but Morfit recommends the following method. Heat to 154½° (310° F.) a mixture of 350 lb. hot-pressed fatty acids, 150 lb. white oleic acid, 200 lb. best rosin. To this, add 135 lb. Jarrow 52° ash (p. 1771) in 25 gal. boiling water. When the soap-paste is quite homogeneous, which should be in about an hour, add 250 lb. pure glycerine, and stir well. If a sample be not transparent when cold, add glycerine until this is the case, controlling the amount of glycerine by testing 2-lb. samples of the soap with glycerine over a gas flame. This soap has the following composition:—Fatty acids, 34·0; rosin, 13·0; soda, 4·6; water, 15·4; glycerine, 33·0.

Since it is beyond the scope of this article to devote more space to the detail of this part of the subject, it may be mentioned briefly that the various shaving-soaps and creams are wholly or in great part potash-soaps; that soap-essences are usually alcoholic solutions of soft-soap; that opodeldoc is a solution of soap in enough alcohol to make a jelly when cold; that "floating" soaps are made by dissolving soaps in a small quantity of water, and agitating the solution violently in contact with air; and that powdered soaps are made from any pure soap, cut into shavings, thoroughly dried, and then ground to fine powder and sifted. It may also be well to call attention to the fact that nearly all the so-called washing-powders, soap-powders, and essences of soap, frequently contain no soap at all, and are merely mixtures of soda-ash, common salt, and sulphate of soda, with occasionally a trace of dry powdered soap.

Theory of the Action of Soap: its Valuation and Analysis.—The mode in which soap facilitates the removal of dirt is by no means clearly understood, and probably depends upon a variety of causes, partly physical, partly chemical. Unquestionably much of its power is due to the alkali it contains, which unites with and renders soluble the grease that forms so large a portion of much of our dirt; but it can hardly be true, as is maintained by some, that the value of a soap depends solely upon its percentage of alkali, since, if that were so, solutions of silicate, carbonate, or aluminate, of soda, containing the same percentage of soda as soap, ought to do as much work, which is notoriously not the case. Further, since the proportion of alkali in a soap is inversely as the equivalent weight of its fatty acids, those soaps with fatty acids of the smallest equivalent weights (e.g. coco-nut-oil) ought to be the most advantageous. Gräger, who advocates this view, gives the following table of anhydrous soaps.

	Equlv. Weight.	Quantity of soap necessary to do the same work as 100 tallow soap.
Oleic acid soap	3800·95	115·1
Palm-oil soap	3558·85	108·7
Tallow soap ..	3300·95	100·0
Coco-nut-oil soap ..	3065·45	92·8

Cold water never is in contact with an alkaline stearate or oleate (the soap of commerce therefore) without decomposing it; the neutral salt is resolved into alkali, which dissolves, and an acid salt, which is precipitated as insoluble. Hence soap even in the purest cold water produces turbidity, although, when treated with *warm* water, it dissolves entirely. Again, since every kind of soap, when it leaves the copper, is a more or less concentrated solution of anhydrous soap in water, when cold and firm, it also is subject to the same decomposition; this is the cause of the slender silky crystalline fibres set in a semi-transparent matrix, so often seen especially in "neat" soaps.

When soap is rubbed in use against the surface to be cleansed, it is obvious that its greater or less hardness is an important consideration, since a harder soap requires much labour to detach enough, while a softer soap wastes away rapidly. It has been already shown that, *ceteris paribus*, the hardness of a soap depends upon how much potash it contains; but where soda only is the base, the question of the comparative solubilities of the soda salts of the fatty acids has to be considered. While oleate of soda is freely soluble in 10 parts of water, stearate of soda is scarcely affected thereby; or in other words, the salts of oleic acid are far more soluble than those of stearic. Hence the hardness of a soap depends, not merely upon the base used, but upon the relative quantities of stearic and oleic acids in its composition; this point will be again referred to in the analysis of soaps.

The impurity of the water employed with soap has a material influence upon its consumption. Rain-water, and next to it, river or lake-water, is the best, while spring-water should be avoided if possible; all such water is more or less "hard," owing to the presence in it of salts of lime (chiefly the carbonate and sulphate), some of which may be removed by boiling, or, more completely, by the addition of carbonate of soda. When a soluble soda-soap comes into contact with lime salts in solution, mutual decomposition occurs, resulting in the formation of insoluble lime-soaps, which have no detergent action. Until all the lime has been thus removed, the soda-soap refuses to cleanse, and hence much of it is wasted. It is obvious also that the presence of any acid in the water, or on the surfaces to be cleansed, will decompose soap, uniting with its alkali, and destroying its detergent power. When nothing but hard water can be procured, or when much grease has to be removed, no soap will be found so economical as the old-fashioned curd-mottled, entangled in the interstices of which are appreciable quantities of caustic soda leys.

Considerable light has been thrown upon the manner of removal of dirt by soap, by the researches upon *Pedesis* of Prof. W. Stanley Jevons, F.R.S., who has given this name to a microscopic phenomenon long known as the "Brownian movement" of small particles. When clay is stirred up with water, and the water allowed to stand, it clears itself very slowly, and microscopic examination showed that this was due to a kind of molecular movement of infinitesimally small particles of the clay. To this movement, Prof. Jevons gave the name Pedetic action (*vid.* 'Quarterly Journal of Science' for April, 1878, No. LVIII.), and he found that it was largely influenced by the addition of certain substances to the water containing clay in suspension. Soap and silicate of soda enormously increased the Pedetic action, or movement of the particles (Report of the British Association for the Advancement of Science, 1878, p. 435), and from observations made by Prof. Jevons, and by the writer of this article (who hopes to extend his researches in this direction), it seems clear that in the action of these substances in promoting this molecular movement of extremely minute particles, is to be sought part of the explanation of the cleansing power of soap.

There are few things which are so ill understood in practical life as the *real value*, or, what is the same thing, the proper price of soap. From what has been said, it appears clear that the real value depends upon the amount of dry (anhydrous) soap present, and upon the proportion of stearic, palmitic, and margaric acids to oleic, and to that of the cocinic, laurostearic, &c. In other words, the determination of the following elements is necessary to arrive at an estimate of the value of a soap:—(1) The percentage of water; (2) the percentage of soda available for detergent purposes (*a*), combined with the fatty acids, (*b*) as caustic, carbonate, silicate, or aluminate; (3) the percentage of fatty acids; (4) the melting-point of those fatty acids (see Candles; and Oils, Detection and Analysis, p. 1477).

It would be very greatly to the advantage of all large consumers of soap, as well as to soap-manufacturers themselves, if soaps were to be sold guaranteed to contain so much per cent. of fatty matter of a given melting-point, combined with the full quantity of soda necessary for its complete saponification.

Brief instructions will now be given for the most suitable methods, consistent with accuracy, for the analysis of soap; for fuller information, manuals of technical chemical analysis should be consulted.

Uniformity of Sample.—Great care should be taken to ensure this; since soap loses water rapidly on exposure, the soap should be sliced up in thin pieces, well shaken, and kept in a well-stoppered bottle. Other convenient plans are (1) to weigh out at once all portions required for analysis, (2) to make a standard solution of the soap, say 100 *grm.* in 1 *lit.*, and measure off what is required, taking care to avoid loss by evaporation. In analysing case-hardened soaps (p. 1783), care must be taken to see that the section of the bar includes a proper proportion of skin; sometimes separate analyses have to be made of different parts of a bar of these soaps.

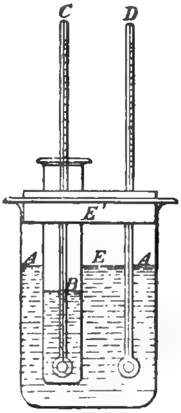
Percentage of water.—About 2 *grm.* of the soap is exposed in a wide-mouthed flask of about 100 *cc.* capacity, to a temperature of 149° (300° F.) in an air- or oil-bath for one hour, and the loss in weight is noted. The flask should be weighed as soon as it is cool, and, where great accuracy is required, should be cooled under a bell-glass in presence of a strong oil of vitriol, as anhydrous soap is very hygroscopic. The operation may be shortened by one-half if a few drops of alcohol be added as soon as the soap has melted; the addition of a known weight of fine dry sand prevents the soap from swelling up too much. No well-made soap should turn brown or discoloured at this temperature.

Percentage of Soda.—A burette (Fig. 1237, p. 1768) is provided, divided into fifths of a cubic centimetre, and a standard solution of acid, such as is directed in works on alkalimetry; either sulphuric or oxalic acids may be used. To determine the *total* percentage of soda present, dissolve 5 *grm.* of the soap in boiling water, and add to it the standard acid solution, stirring and boiling the whole time, until a permanent froth is no longer visible; from the number of *cc.* of acid used, the amount of soda is readily calculated. To determine the soda uncombined with fat, dissolve 10 or 20 *grm.* in water, add enough sodium chloride to precipitate the soap, remove the liquor, re-dissolve the soap in fresh water, repeat the operation, mix both brine solutions together, and estimate the soda therein by standard acid, using litmus to determine when enough has been added. The second result subtracted from the first gives the percentage of soda combined with fatty acids.

Percentage and Examination of Fatty Acids.—A known weight of the soap (10 or 20 *grm.*, if only the percentage is required, 50 or 100 *grm.* if the nature of the fat is to be ascertained) is dissolved in hot water. If any portion refuses to dissolve, as will be the case if steatite, clay, or starch have been mixed with the soap, the solution must be filtered, either in a hot closet, or through a funnel surrounded by hot water; if the filter be previously weighed, the insoluble portion can be weighed upon it after being washed and dried at or above 100° (212° F.); to the clear soap solution, an excess of sulphuric or hydrochloric acid is added, and the whole is gently boiled until the fatty acids are clear and transparent, and all clots have disappeared. If there is reason to believe that the fatty acids will be fluid, or even soft, and greasy, at the ordinary temperature, and a fat percentage only is desired, a weighed quantity of white wax or stearic acid, previously deprived of water [see Oils, p. 1462, (1) *a.*], should be added at this stage. When the cake of fatty acids is cold, the liquid beneath should be removed, and the cake remelted over fresh hot water, to remove all traces of salts and acids. When cold, it may be partially dried with blotting-paper, if it is solid enough not to give up any oleic acid to that absorbent; it should then be all carefully transferred to a tared capsule, heated to at least 127° (260° F.) to expel the last traces of mechanically mixed water, and then weighed, the weight of wax or stearic acid added being of course deducted. Every 100 parts of fatty acids so obtained, represent 105–106 parts of pure neutral fat used to make the soap. In this condition, the fatty acids are hydrates, and from every 100 parts, 3·5 parts must be deducted in stating the analytical results for water chemically combined with them, because anhydrous soap [dried at 149° (300° F.)] does not contain these elements of water.

To ascertain the nature of the fatty acids, the melting-, or solidifying-point of the mixture should first be taken (see Oils, p. 1477). The apparatus suitable is shown in Fig. 1278. The fatty acid is in the inner tube B, surrounded by water, which is gradually heated over a lamp; temperatures are observed by thermometers C D. To detect the presence of, and estimate, coco-nut-oil or palm-kernel-oil, the method recommended in Oils, p. 1746, may be adopted. On the same page, will be found hints for the determination of the quantity of rosin; another method (proposed by Dalican) is here given, with the remark that Sutherland's process, by which the rosin is oxidized by nitric acid, and Rampal's process, in which the rosin is precipitated in a finely-divided state by throwing an alcoholic solution of the fatty acids into water, are both unreliable. Dissolve 10 *grm.* of the soap in 100 *grm.* water, add enough concentrated soda leys to precipitate the soap (p. 1769); some resinates remain in the liquor, which is neutralized, evaporated to dryness, and the resin extracted with alcohol, which may be distilled off, and the rosin weighed (A). Then dissolve the precipitated soap in water, and add excess of barium chloride; collect and dry this baryta soap, and extract it with ether, which dissolves out only the resinates. Evaporate off the ether, and treat the resinates with boiling water and sulphuric acid, which sets the rosin free; it may then, if necessary, be similarly dissolved out by alcohol, or may be merely collected on a weighed filter, and its weight (B) noted; A+B is the weight of rosin in the soap. The portion insoluble in ether may then be suspended in water, decomposed with sulphuric acid, and the fatty acids collected, dried, and weighed.

1278.



For other methods of examining the nature of the fatty acids in soaps, consult Oils—Detection and Analysis, pp. 1462–1477, to which may be added a reference to the amount of information that may be derived from examining, by polarized and ordinary light, under a microscope, the manner of crystallization of thin layers of fatty acid mixtures allowed to cool between two pieces of glass pressed together; some very remarkable results of this method were shown by Price's Candle Co. at the Paris Exhibition of 1878.

Shorter, but less reliable, methods than the above have been frequently proposed for determining the value of soap. To shorten the operation of weighing the fatty acids, many methods have been proposed for measuring them, by collecting them in a long-necked flask, graduated, or in a graduated tube attached thereto. Whenever this is done, the weight can only be arrived at from the estimated sp. gr. of the fatty acids, and as this is very variable, the method is at best an approximate one, though useful in the factory when that sp. gr. is known. Buchner decomposes 16·66 *grm.*, and measures the fatty acids to the ¼*cc.*, multiplying by 0·93 to get the weight in *grm.* He also gives the following useful table, on the basis that 100 lb. fat produce 155 lb. soap and about 6·25 lb. glycerine; the three last columns are of general use, when the "fatty acids per cent." are determined by weight:—

No. of *cc.* of fatty acids from 16⅔ *grm.* soap.	Sp. gr. of fatty acids.	Mean weight of the fatty acids in *grm.*	Fat used for 100 lb. soap.	"Neat" or grain soap in 155 lb. of soap examined.	100 parts of the soap contain of water, soda, glycerine, &c.	100 parts of the soap contain of real grain soap.
0·5	0·93	0·46	3·13	4·85	97	3
5	"	4·65	31·30	48·50	69	31
6	"	5·58	37·56	58·20	63	37
7	"	6·51	43·82	67·90	57	43
8	"	7·44	50·08	77·60	51	49
9	"	8·37	56·34	87·30	44	56
10	"	9·30	62·60	97·00	38	62
11	"	10·23	68·86	106·7	32	68
12	"	11·16	75·12	116·4	26	74
13	"	12·09	81·38	126·1	20	80
14	"	13·02	84·64	135·8	13	87
15	"	13·95	93·90	145·5	7	93

The Industrial Society of Mulhouse awarded a prize to Cailletet for a method of analysing soap without more weighings than that of the soap itself. Minute instructions are given in the Bulletin of the Society, No. 144, Tome xxix., p. 8. Suffice it to say here that, in the first place, much information may be gained for industrial purposes by attentively observing the behaviour of the soap with hot and cold water; 10 *grm.* of the soap are then decomposed by excess of standard acid in presence of a measured volume of turpentine-oil, the increase in volume of which, multiplied by the sp. gr. of the fatty acids, gives their weight. The acid solution is titrated back with soda, and the soda per cent. is calculated. It is stated that the turpentine does not dissolve the rosin, and that thus the presence of rosin may be detected, and even estimated.

A short way of ascertaining whether there is much besides pure soap, and water, in a sample of soap, is to treat it with strong warm alcohol, which dissolves nothing but the soap, and excess of caustic soda, if any; this last may be removed by a stream of carbonic acid gas. The insoluble residue may be collected on a tared filter, washed with alcohol, dried, and weighed.

The determination of the other constituents of commercial soaps has now to be considered.

Unsaponified fat.—This is very rarely present; 10–20 *grm.* of the soap is cut into fine shavings, and dried at 100° (212° F.); then treated with warm benzol or petroleum-spirit, which is decanted or filtered off into a tared flask; the solvent is then distilled off, or evaporated, when the unsaponified fat, if any, is left behind and weighed.

Glycerine.—A weighed portion of the soap is dissolved in water, and decomposed with slight excess of sulphuric acid; the fatty acids are removed, and the acidulated solution is evaporated to dryness and treated with alcohol; the alcoholic solution of glycerine is separated by filtration into a tared flask, from which the alcohol itself is distilled off.

Carbolic acid.—Mr. C. Lowe recommends the following process. Take 50 grain-measures of aqueous solution of caustic soda sp. gr. 1·345, dilute to 1000 gr.-m.; in this, dissolve by heat 100 gr. of the soap, then add 1000 gr.-m. saturated solution of common salt. Filter off, and wash with brine, the soap thus precipitated; slightly acidify the filtrate and washings with hydrochloric acid, and add thereto enough bromine-water to make the liquid permanently yellow. Warm the liquid till the precipitate melts, then let it cool; remove, carefully dry, and weigh the resulting mass, of which, 331 parts correspond to 94 parts of carbolic acid. If the inferior qualities of carbolic acid have been used, the precipitate, which is bibromocresol, $C_6H_3Br_3O$, forms a sticky mass, owing to the liquid nature of the cresylic acid it contains.

The determination of soluble silica and alumina (as silicate and aluminate of soda), of sulphuric acid (as sulphate of soda), of chlorine (as common salt), and of other mineral constituents of soap, must be made in the acid solution that remains after decomposing the soap with a suitable mineral acid; the estimation of carbonic acid (as carbonate of soda) presents great difficulties. The ordinary methods of inorganic quantitative analysis may be applied in these cases.

Substances Insoluble in Water.—In a properly-made unadulterated soap, these should only consist of colouring matters and mottling. To estimate their amount, dissolve a known weight in water, decant the clear liquid, collect the deposit on a tared filter, wash, dry, and weigh. Organic impurities may be estimated by igniting this residue, and weighing again, when only mineral impurities remain. Starch or farina is detected by iodine; mineral impurities, by the ordinary methods of mineral analysis.

Two or three examples of freshly-made analyses of hard soap are here given; no deduction is made for water combined with the fatty acids (p. 1794).

A good "Primrose" Yellow Soap.

	Per cent.
Water	32·8
Total Soda	6·7
Sodium Chloride	0·2
Fatty Acids	62·3
	102·0

An old-fashioned Grease Mottled Soap.

	Per cent.
Water	29·8
Soda with fat	7·0
Free Soda	0·6
Sodium Chloride	0·1
Fatty Acids	64·7
	102·2

A genuine "Cold-water" Soap.

	Per cent.
Water	22·0
Soda with fat	7·3
Soda with silica, &c.	0·8*
Silica	1·6
Sodium Chloride and Sulphate	0·4
Fatty Acids	70·2
	102·3

* Or 5·0 per cent. sil. soda sp. gr. 1·700.

A Blue (red, or grey) Mottled Soap.

	Per cent.
Water	44·3
Soda with fat	5·2
Soda (free, or) as Silicate	0·8
Silica	1·3*
Sodium Chloride	0·8
Sodium Sulphate	0·3
Mottling and Insoluble	0·7
Fatty Acids	47·5
	100·9

* Equal to 3·9 per cent. silicate of soda at 1·700 sp. gr.

A neutral Curd Soap, for Manufacturers.

	Per cent.
Water	28·0
Soda with fat	7·0
Soda free, &c.	0·0
Sodium Chloride	0·2
Fatty Acids	67·9
	103·1

A few remarks upon the location, prospects, legislative condition, and other general considerations connected with the soap-trade, may fitly close this portion of the article.

This industry is by no means localized in any one part of the British Islands; but, although the total amount of soap made in England is probably greater now than it ever was, the tendency of the last 25 years has been in the direction of concentrating the manufacture in the hands of a few firms. Among these, may be mentioned, W. Gossage & Sons, Widnes, Lancashire; Jos. Crosfield & Sons, Warrington; Hodgson & Simpson, Wakefield; Cook & Sons, Anderson & Cattley, and Cowan & Sons, all of London; Christopher Thomas & Bros., and Lawson, Phillips, & Billings, both of Bristol; Tennant, of Glasgow; Hedley & Sons, Newcastle-on-Tyne; and others. Probably the oldest soap-works in the country are, or at any rate until recently were, to be found in Bristol, which still retains great reputation for its soap. A relic of this may be found at the present day in Holland, in some parts of which no soap can be sold which is not stamped with the word BRISTOL. Of the two soap-works mentioned as now left in that city, the former, belonging to Christopher Thomas & Bros., was established in 1745.

The abolition of the duty on soap in 1853, then about 2*d.* a lb., and producing a revenue of upwards of 1,000,000*l.*, naturally gave an immense impulse to improvements in the manufacture, and various valuable patents were very shortly taken out, the most important of which were those of W. Gossage for silicated soaps, that of T. Thomas for cheap detergent soaps made from mixtures of neat soap, silicate of soda, and sulphate of soda, that of Blake & Maxwell for hydrated soaps (p. 1777), and those of C. N. Kottula, for various improvements in the making of blue-mottled and other soaps. An association of soap-manufacturers in England holds quarterly meetings, at which prices are revised, common action agreed upon, and legislative enactments affecting the trade discussed and watched. All soap-factories, in common with other factories, are subject to inspection by Factory Inspectors acting under the Government, and to the visits of a Certifying Surgeon. In a well-managed soap-works, the sources of nuisance are very slight, and comparatively inoffensive; most of them arise, not from the actual process of soap-making itself, but from the preliminary operations of refining, purifying, and bleaching the fatty matters employed (see Oils, p. 1448, and pp. 1458–1462). They may all be obviated by conducting such operations in closed vessels provided with trunks communicating with the draught of a flue; when impure and rancid fats are used direct for soap-making, the copper should be provided with a cover and a similar trunk. In default of a flue-draught, a fan, or a jet of steam, may be used to create a good current of air.

Since the removal of the duty, there are few means of forming an estimate of the extent of the soap-trade in England; it is known, however, that many of the larger houses make much more than 5000 tons a year, while a few make over 10,000, and it is stated that one house is capable of turning out 500 tons in a week when necessary.

The total annual production in the United Kingdom was estimated at 250,000 tons by Prof. Roscoe, in his inaugural address as President of the Society of Chemical Industry, in June 1881. Our exports of soap in 1880 were as follows:—To the British W. Indies and British Guiana, 69,527 cwt., 71,302*l.*; British S. Africa, 66,563 cwt., 72,928*l.*; Java, 34,013 cwt., 31,510*l.*; China, 30,420 cwt., 28,172*l.*; Spain and Canaries, 24,430 cwt., 24,529*l.*; Portugal, Azores, and Madeira, 23,289 cwt., 24,949*l.*; Gibraltar, 14,897 cwt., 15,455*l.*; Italy, 11,883 cwt., 14,442*l.*; foreign W. Africa, 10,962 cwt., 10,572*l.*; Bombay and Sind, 10,928 cwt., 14,956*l.*; Bengal and Burma, 10,765 cwt., 16,098*l.*; foreign W. Indies, 10,170 cwt., 10,798*l.*; Australia, 7287 cwt., 13,433*l.*; Hong Kong, 7158 cwt., 8334*l.*; Holland, 5674 cwt., 5617*l.*; Channel Islands, 4328 cwt., 6868*l.*; British N. America, 3513 cwt., 4925*l.*; France, 1842 cwt., 4598*l.*; other countries, 44,159 cwt., 60,509*l.*; total, 391,808 cwt., 440,286*l.*

In France, the chief seat of the industry is at Marseilles, while a not inconsiderable amount of common, and nearly all the toilet, soaps are made in Paris. In a report on the exhibits at Paris in 1878, it was stated that the French soap-trade had been for some time stationary at about 220,000 tons per annum, but was then declining, owing to practices not very creditable to the manufacturers.

In Germany, and other parts of the Continent, soft soaps are much more proportionately in vogue for laundry and other purposes, than in England, while the chief hard soaps made are for toilet purposes.

In the United States, Kirk & Co. of Chicago have probably the largest trade, but they are closely approached by Babbitt & Co., and Colgate & Son, of New York. The changes that have lately passed over the trade in America have been already described (p. 1787). It may be said, without fear of contradiction, that while perhaps for fancy toilet soaps the palm must be given to France, England and the United States are pre-eminently the countries where the manufacture of the different varieties of soap is most clearly understood, and carried out on the largest scale, and in the best manner.

Railway- and Waggon-grease.—The first of these consists essentially of a mixture of a more or less perfectly formed soap, water, carbonate of soda, and neutral fat, and is used on the axles of all locomotives, railway-carriages, and trucks that are provided with axle-boxes; while the second is a soap of lime and rosin-oil, with or without water, and is used on all railway-trucks unprovided with axle-boxes, and for ordinary road-vehicles.

The requisites for a good "locomotive-grease" for high velocities are:—(1) a suitable consistency, such that it will neither run away too rapidly, nor be too stiff to cool the axles; (2) lasting power, so that there may be as little increase of temperature as possible in the axles, even at high speeds; (3) a minimum of residue in the axle-boxes.

In practice, it is found that a grease containing 1·1–1·2 per cent. soda (100 per cent.) gives the best results. The process of manufacture is very simple; Morfit's soap-pans, provided with stirrers, p. 1772, Fig. 1240, are the most suitable vessels for the purpose. The fats, usually tallow and palm-oil, are heated to 82° (180° F.), and into them, are run the carbonate of soda and water heated to 93½° (200° F.), and the whole is well stirred together, and run into large tubs to cool slowly. Many railway companies buy a curd-soap made from red palm-oil, dissolve it in water, and add thereto enough tallow and water to bring the composition of the whole to the desired point. It is usual to allow 2½ per cent. for loss by evaporation of water during the manufacture. The composition has to be slightly varied according to the season of the year; the following formulæ for mixing have stood the test of successful experiment; the summer one ran 1200 miles. It should be carefully borne in mind that a chemical analysis of locomotive-grease is no test whatever of its practical value, which can only be determined by actual experiment.

	Summer.	Winter.
	per cent.	per cent.
Tallow	18·3	22·3
Palm-oil	12·2	12·2
Sperm-oil	1·5	1·2
Soda crystals	5·5	5·0
Water	62·5	69·3
	100·0	100·0

The "waggon-grease" is thus prepared. A good milk of lime is made, and run through several overflow-tubs, where all grit is deposited; it is then drained on canvas. If the grease is to be made without water, the paste must be agitated with rosin spirit, which expels the water, and it is then thinned with a further quantity of rosin spirit. The aqueous milk of lime, or the mixture of lime and rosin-spirit, is then stirred together with a suitable quantity of rosin-oil in a tight barrel furnished with a shaft and stirrers, without the application of heat, after which, the whole is run out into barrels to set. Many other ingredients are often stirred in, such as "dead oil," petroleum residues, graphite, sea-weed jelly, silicate of soda, oil refiners' foots, micaceous ores, steatite, Irish moss, &c.

A careful estimate was made in 1865, compiled from various reliable sources, by Watts, of the total quantity of anti-friction greases made in the United Kingdom in a year, of which the following is an abstract:—

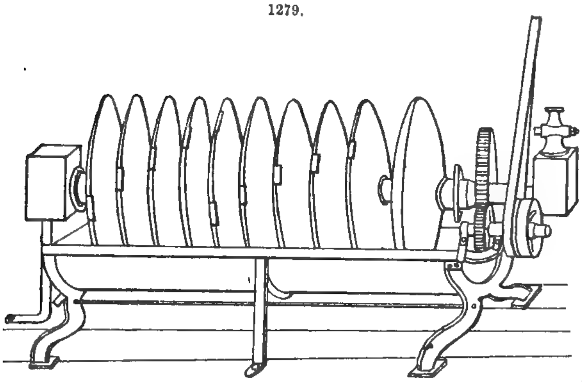
		Tons.
Railways	11·7 cwt. per mile per year	6,358
	1·42 cwt. per 1000 tons coal	6,108
	Other minerals, &c.	711
	Agricultural carts	2,130
	Trade and other carts, &c.	2,070
	Total	17,377

Glycerine (Fr., *Glycérine*; Ger., *Oelsüss*, *Oelzucker*, *Glycerin*).— Few things in the history of chemical industry are more wonderful than the enormous development in the use of this substance, which, a few years ago, was thrown away as a waste product, but which now finds so many useful applications in the arts and sciences. The researches of Chevreul, which demonstrated the constitution of fats, showed that glycerine exists in nearly all neutral fats (see p. 1764) in a combined state, and small traces of it have lately been discovered uncombined in palm-oil. It is formed, as Pasteur has shown, in the process of fermentation, 100 parts cane-sugar forming 3·5 parts of glycerine. Recent researches have also made it clear that its compound with phosphoric acid is the starting-point of a number of complex constituents of the brain. For practical purposes, however, glycerine is always obtained from the bye-products of candle-, and quite lately, of soap-factories. Cap worked out the first process for preparing it on a commercial scale from the waste liquor of the saponification of tallow by lime, in the first stage of stearic acid making (see Candles, p. 579). Early in 1854, Tilghman produced it by pumping an emulsion of 2 parts tallow and 1 part water through a coil of pipe heated to 322° (612° F.), after which, the emulsion separated into two layers, the upper one of fatty acids, and the lower of glycerine and water. Several modifications of this were afterwards patented, but the only one worked on a large scale was that of G. F. Wilson and G. Payne, dated July 24, 1854, under which, enormous quantities of glycerine have been made by Price's Candle Co. In this process, neutral fats are put into a still provided with a fine steam-worm, and a fractional condensing apparatus of large surface, similar to that described in Candles, p. 581; they are then heated to between 288° and 315° (550°–600° F.), and plenty of superheated steam is injected; mixed vapours of fatty acids, glycerine, and water are carried over to the condenser, where the divisions nearest the still collect only fatty acids, while those farthest from it yield mixtures of fatty acids with glycerine and water in various stages of concentration. Glycerine so made can be concentrated in a vacuum-pan. Care must be taken that the temperature does not exceed 315° (600° F.), and that plenty of steam is present, else some of the glycerine is decomposed, and acrolein, a compound most irritating to the eyes, is formed—

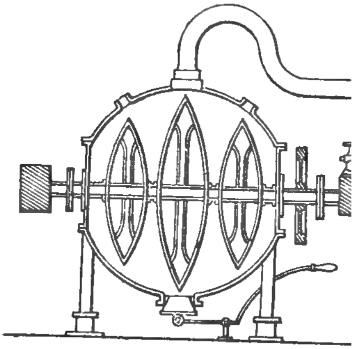
$$\begin{array}{ccc} \text{Glycerine} & = & \text{Water} + \text{Acrolein} \\ C_3H_8O_3 & = & 2H_2O + C_3H_4O \end{array}$$

Raw glycerine is also prepared from the water employed to wash the fatty acids after acidification (p. 581) of the neutral fats. The acid liquid is neutralized by carb. lime, or carb. baryta, either of which may be added until effervescence ceases; it is then concentrated to 28° B. in an open, shallow, cast-iron pan. Of late, however, glycerine has become sufficiently valuable to cause candle-manufacturers to adopt that method of preparing fatty acids which gives them the greatest yield of glycerine from neutral fats. This process, called the autoclave, as patented by De Milly on Nov. 19, 1856, is now very extensively used for glycerine making, both on the Continent of Europe and in England, and is thus conducted. About 1 ton of fat, usually mixed tallow and palm-oil, is heated with 2 per cent. lime and $\frac{1}{3}$ the fat-volume of water in an upright Papin's digester to 8 atmos. pressure for 4 hours. The whole is then blown out into a tank, and the "sweet-water" is run off. The lime-soap is decomposed in the usual way with sulphuric acid, and the resulting fatty acids are either pressed, or acidified and distilled for stearic acid. (See Candles, p. 581.) It is then concentrated in a modification of the "Wetzel" evaporating-pan (originally introduced for sugar-boiling), constructed by Chenaillier, Paris. This *évaporateur universel*, as he terms it, which is very economical and effective, is shown in Fig. 1279, and consists essentially of pairs of saucers set edge to edge upon a hollow central revolving shaft, through which, steam passes to the interior of the saucers (the waste steam from a high pressure engine will do); the lower edges of the saucers dip in a jacketted trough of the liquid to be evaporated, and when they are revolved, layers of this are brought up and speedily concentrated on their surface. It may also be worked in a vacuum as shown in Fig. 1280.

1279.



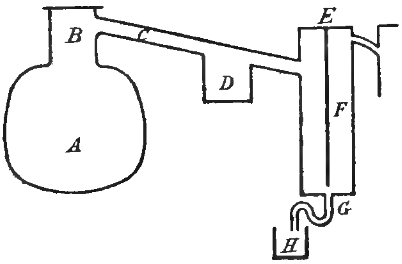
1280.



Evaporation is continued to 26° B., when the glycerine is of a brownish colour, and known as "raw," in which state it is sold for many purposes. At Price's Candle Company's works the further purification is conducted as follows. The raw glycerine, sp. gr. 1·245–1·250, is heated in a jacket pan with that kind of animal charcoal known as ivory-black, and is then distilled; this alternate treatment is repeated as often as may be necessary. The distillation is performed with superheated steam in a copper still provided with copper fractional condensers (the same as shown in Fig. 463, p. 581, but omitting the right half of the apparatus, including the tanks G), the still being also heated externally; the operation is performed at as low a temperature as is consistent with distillation, usually about 227° (440° F.). The number of distillations depends upon the quality of the raw glycerine and the purity of the product demanded. Of the six runs, Nos. 1, 2, and 3 usually give pure glycerine, while the dilute condense-products from Nos. 4, 5, and 6 are generally returned to the still, though occasionally concentrated in an *évaporateur universel*, or in a vacuum-pan. Some stills hold as much as 3 tons, but they are usually smaller, and in all cases the process is conducted very slowly. A form of still and condenser much used on the Continent of

Europe is outlined in Fig. 1281. External heat and injected superheated steam are used to effect distillation. The still A has an unusually large head B, and the goose-neck C is provided with a catch-box D, in case the still-contents should, as sometimes happens, boil over; the fractional condensers E are upright cylinders with longitudinal partitions F running nearly their whole length; the condensed products run out through G into receptacles H. The whole apparatus is of iron, and usually made to distil ½ ton at a time; in some cases, the process is conducted continuously, with a properly arranged feed.

1281.



Enormous quantities of glycerine are run to waste in the spent leys (p. 1779) of the soap-maker. One of the earliest attempts to extract it was a patent by H. Reynolds, June 10, 1858, for concentrating the spent leys, and distilling off the glycerine by superheated steam between 193½° and 204½° (380°–400° F.); the large quantity of sodium salts, especially sodium chloride, were found, however, to be an almost insuperable difficulty. On March 31, 1879, a patent was taken out by C. Thomas, W. J. Fuller, and S. A. King, of Broad Plain Soap Works, Bristol, by which process the first successful production of crude glycerine from spent soap leys was introduced into commerce, and several tons per week are now manufactured. The specification states:—"We evaporate the spent or partially spent leys until the boiling-point of the liquid rapidly rises, when nearly all the salts that can be thrown down by simple evaporation are deposited in the pan. The resulting liquor is chiefly composed of raw or impure glycerine. This we draw off into a second pan, and boil it with excess of fatty acid, which, readily combining with some of the salts in solution, separates them from the liquor, and at the same time removes from it the fine crystals of salt formed during this operation. After this treatment, we skim off the saponified fatty matter, allow the liquid to cool, and filter it to remove the gelatinous, albuminous, and other impurities. The clear liquid may then be refined, distilled, or concentrated, as desired."

The recent extremely rapid rise in the price of glycerine has caused much attention to be directed to this abundant source of it. Victor Clolus, of Billancourt, near Paris, has patented a process for its recovery from soap-boiler's waste, which will (Oct. 1881) shortly be worked in England also; and H. Flemming, of Kalk, has patented in Germany (No. 12,209) a process for removing glycerine from spent leys by dialysis, a membrane of parchment-paper serving as the diaphragm through which the crystalline salts present in the glycerine diffuse themselves. Another process has been proposed, according to which, the salts are said to be removed from spent leys by saturating the latter first with carbonic acid gas, and then with hydrochloric acid gas.

Although evaporation and distillation are the usual methods of purifying glycerine, the action of cold upon more or less dilute glycerine is sometimes employed in conjunction with them, especially by Sarg, at Vienna. When an aqueous solution of glycerine partially freezes, the frozen mass contains more water than the remaining liquid, hence some amount of concentration may be thus effected. The following table gives the freezing-points of such mixtures:—

Glycerine Per Cent.	Sp. Gr.	Freezes.	Glycerine Per Cent.	Sp. Gr.	Freezes.
10	1·024	− 1° C.	60	1·159	Below − 35° C.
20	1·051	− 2°·5	70	1·179	
30	1·075	− 6°	80	1·220	
40	1·105	− 17°·5	90	1·232	
50	1·127	− 31°·3	94	1·241	

Another authority gives:—

Glycerine solution sp. gr.	10° B.	12° B.	14° B.	15° B.
Melting-point ..	− 9° C.	− 13° C.	− 18° C.	− 21° C.

In January 1867, some glycerine sent in tin cans from Germany to England froze into pea-sized octahedral crystals; these, while melting, had a constant temperature of 7°·2 (45° F.), but would not freeze again even when cooled to − 18° (0° F.). According to Werner, commercial glycerine will freeze more readily if chlorine gas be passed into it. In purifying glycerine by cold, the whole mass is cooled to nearly 0° (32° F.), and some crystals of solid glycerine are added; almost the whole mass solidifies on agitation, and a centrifugal machine is used to separate the solid from the liquid parts. Treated in this way, glycerine at 28° B. yields crystals which, when melted, are 30°·8 B.

Pure glycerine is a viscid, colourless, and transparent liquid, with an intensely sweet taste, soluble in water in all proportions, in alcohol, chloroform, and carbon bisulphide, but not in ether; its sp. gr. is 1·267; it solidifies at − 40° (− 32° F.) to an amorphous mass. When distilled, it decomposes, unless steam be present, hence its boiling-point cannot be accurately determined at atmospheric pressure. According to Bolas, at 12·5 *mm.* pressure, it boils at 179°·5 (355° F.), and at 50 *mm.*, at 210° (410° F.), while Heminger gives 179° (354° F.) as its boiling-point under 20 *mm.*

It burns with a clear flame like oil, if there be free access of air, and a high temperature for kindling it.

From one point of view, in its chemical relations it is an alcohol, and although the ferments that excite alcoholic fermentation will not ferment pure glycerine, it may be fermented by a hitherto undescribed *bacterium*. Just as acetic acid and alcohol, interacting, form water and acetic ether, so acetic acid and glycerine, interacting, form water and *mon*acetin. *Tri*acetin is a natural glyceride, occurring in cod-liver-oil. This brings to mind the other aspect of glycerine, viz. as the base of the natural glycerides, in which, it requires three equivalents of a fatty acid, and hence is considered a tri-acid base, or, in the language of modern chemistry, a trivalent alcohol radicle. Its formula on this view is $C_3H_5(OH)_3$, and its relation to its most abundant sources is here shown :—

Tristearin	$C_3H_5\ (OC_{18}H_{35}O)_3$	Tallow.
Triolein	$C_3H_5\ (OC_{18}H_{33}O)_3$	
Tripalmitin	$C_3H_5\ (OC_{16}H_{31}O)_3$	Palm-oil.
Triricinolein	$C_3H_5\ (OC_{18}H_{33}O_2)_3$	Castor-oil.
Tributyrin	$C_3H_5\ (OC_4H_7O)_3$	Butter.
Triacetin	$C_3H_5\ (OC_2H_3O)_3$	Cod-liver-oil.

Next to water, glycerine is the most powerful solvent known. It dissolves bromine, iodine, and carbolic acid better than water does. Klever gives a long table of the solubilities of different substances in 100 parts of glycerine, from which the following is taken:—93 sodium carbonate, 40 alum, 25 green vitriol (ferrous sulphate), 20 lead acetate, 20 sodium chlorate, 0·50 quinine and other alkaloids, 1·9 iodine, 0·20 phosphorus, 0·10 sulphur.

With baryta, strontia, and lime, it forms compounds insoluble in water, not precipitable by carbonic acid. Anhydrous glycerine dissolves caustic potash and soda, oxide of lead, all deliquescent salts, the sulphates and chlorides of potassium and sodium, and of copper, the vegetable acids and alkaloids. It mixes with water in all proportions; the following table will be found very useful commercially:—

Table of Quantity by Weight of Water in 100 parts by Weight of Dilute Glycerine at 17½° (63½° F.).—[F. Hoffmann.]

Sp. Gr.	Per cent. Water.	Sp. Gr.	Per cent. Water.	Sp. Gr.	Per cent. Water.
1·267	0	1·212	17	1·161	34
1·264	1	1·209	18	1·159	35
1·260	2	1·206	19	1·156	36
1·257	3	1·203	20	1·153	37
1·254	4	1·200	21	1·150	38
1·250	5	1·197	22	1·147	39
1·247	6	1·194	23	1·145	40
1·244	7	1·191	24	1·142	41
1·240	8	1·188	25	1·139	42
1·237	9	1·185	26	1·136	43
1·234	10	1·182	27	1·134	44
1·231	11	1·179	28	1·131	45
1·228	12	1·176	29	1·128	46
1·224	13	1·173	30	1·126	47
1·221	14	1·170	31	1·123	48
1·218	15	1·167	32	1·120	49
1·215	16	1·164	33	1·118	50

Commercial glycerine is liable to contain various impurities, arising from its mode of preparation; also certain adulterants, of which cane-sugar and glucose are the chief. Glucose may be detected by the brown colour formed when the suspected glycerine is boiled with caustic soda; cane-sugar is shown by its deposition when the glycerine is agitated with chloroform, or, more certainly, by a polarizing saccharimeter, since glycerine has no rotatory action on the plane of polarization. Lead is detected by sulphuretted hydrogen; lime, by the addition of alcohol and sulphuric acid, a white precipitate of calcium sulphate being formed; butyric and formic acids, by the characteristic smell of their ethers, produced by boiling the suspected glycerine with alcohol and strong sulphuric acid; oxalic acid by the addition of calcium chloride and ammonia; sodium chloride, by the addition of silver nitrate, which should give no precipitate with pure glycerine after 24 hours' standing. A rough and ready test for impurities generally is to agitate the glycerine with an equal bulk of chloroform, when they collect in the intermediate layer.

Traces of glycerine present in other substances, may be detected by the formation of formic ether (which smells of peach-blossom), produced by boiling glycerine with manganese binoxide, alcohol, and sulphuric acid.

The uses of glycerine are very numerous, and are almost daily increasing in number. Its applications in pharmacy are almost endless; it is used wherever a substance requires to be kept more or less moist, e. g. modelling-clay, tobacco, paper for printing, adhesive gum, &c.; also in spinning, "dressing," weaving, rope-making, and tanning. It is used in gas-meters, and in floating compasses, to lower the freezing-point of the water therein used; it is an excellent preservative medium for meat, and for natural history specimens, to which latter purpose it was first applied in 1856 by Dr. Carpenter, F.R.S. Glycerine is also of great importance as the starting-point of other chemical products of great value, one of the most valuable of which is nitro-glycerine, the fabrication of which has been described on pp. 897–902. For this purpose, it must contain no sodium chloride. The engineers of the Panama canal estimate their requirements of nitro-glycerine at a minimum of 8000 tons, equal to about half that quantity of raw glycerine. Besides nitro-glycerine, two other important products are obtainable from glycerine, viz. isopropyl iodide, and allyl iodide, each of which serves as the starting-point of a large series of chemical products, many of them of utility in the arts. They are formed by heating glycerine with hydriodic acid, thus:—

$$C_3H_5(OH)_3 + 5\,HI = 2\,I_2 + 3\,H_2O + C_3H_7I \text{ (isopropyl iodide.)}$$
$$C_3H_5(OH)_3 + 3\,HI = I_2 + 3\,H_2O + C_3H_5I \text{ (allyl iodide.)}$$

When oxalic acid is heated in contact with glycerine, the former breaks up into formic acid and carbon dioxide. This process is much used in the preparation of formic acid, the glycerine employed not being consumed, but merely successively decomposed and recomposed.

The total production of glycerine yearly was estimated by Riche, in a report on the Paris Exhibition of 1878, at 10,000,000 *kilo.*, with a value of 5–6 million *fr.* The production was thus distributed:—France, 4000 tons; Germany and Austria, 1500; Holland, 900; Russia, 900; Belgium, 800; Italy, 400; England, 300; Spain, 100.

Bibliography.—G. E. Loviné, 'Traité de la Fabrication des Savons' (Paris: 1859); H. Dussauce, 'Manufacture of Soap' (Philadelphia and London: 1869); Morfit, 'Soaps' (New York: 1871); C. Deite, 'Der Industrie der Fette' (Brunswick: 1878); R. S. Cristiani, 'Soap and Candles' (Philadelphia and London: 1881); F. Wiltner, 'Seifen-fabrikation' (Vienna). W. L. C.

(See Alkali; Candles; Oils and Fatty Substances; Resinous and Gummy Substances.)

SPICES AND CONDIMENTS (Fr., *Épices*, *Assaisonnements*; Ger., *Würze*).

The terms "spice" and "condiment" are applied to those articles which, while possessing in themselves no nutritious principle, are added to food to render it more palatable. Spices are exclusively of vegetable origin, and generally consist of aromatic fruits. Condiments may be regarded as embracing mineral substances like salt, artificial compounds such as ketchup, and bitters used for provoking an appetite. Salt is so much more important in chemical industries than as a flavouring, that it has been described in a separate article (see pp. 1710–40). The present article will include the dozen and a half spices which chiefly figure in commerce, as well as that foundation of nearly all sauces, the Chinese soy.

Aniseed (see pp. 334–5).—The common anise (*Pimpinella Anisum*) is a native of the Greek, Turkish, and Egyptian shores of the Mediterranean, but is nowhere found growing wild. It is cultivated in Touraine and Guienne (France), near Alicante (Spain), in Puglia (S. Italy), in Malta, in Bohemia, Moravia, and several parts of N. and Central Germany, in the Russian districts of Orel, Tula, Woronesh, and Charkov, in Greece, Morocco, Persia, N. India, and some countries of S. America. Of the fruits forming the common "aniseed" of commerce, there were exported from Mogador, in 1880, 2 serons, 8*l.*, to France; from Bushire, in 1879, 500 *rupees'* worth to India; from Revel, in 1878, 569 *poods* (of 36 lb.) to Great Britain; from Guatemala, in 1878, 16½ *quintals* to Belize.

The true "star-anise," a fruit having exactly the same odour as anise, and from which an oil of anise (see p. 1416–7) is also prepared, is the *hwai hiang* of the Chinese, the fruit of *Illicium anisatum*, a small tree (25–30 ft.) indigenous to the countries lying south of China, and long since introduced into and now largely cultivated in the Chinese provinces of Yunnan and Kwangse. On the other hand, the fruit of the Japanese species (*I. religiosum*), called *skimi*, *fanna skimi*, or *somo* in

Japan, and *ao-wu-su* in China, though occasionally shipped from Japan to this country in ignorance, is a potent poison, and may be distinguished by having neither odour nor flavour of anise, but a smell resembling bay-leaves, and scarcely any taste at all. In English commerce, it is sometimes found mixed with the Chinese star-anise. Chinese anise is imported into Japan for use as a spice.

The fruits of other species deserve mention here as possible adulterants of or substitutes for the genuine star-anise. They are :—(1) *I. parviflorum*, of the hilly regions of Georgia and Carolina, fruit having a sassafras-like flavour; (2) *I. floridanum*, the "poison-bay" of Alabama and Florida, the fruit divided into 13 (instead of 8) carpels or rays, and having the flavour of true star-anise; (3) *I. Griffithii*, on the Bhotan and Khasia Hills at 4000–5000 ft., fruit bitter and acrid in flavour, and having an odour between bay-leaves and cubebs; (4) *I. majus*, on the Thoung Gain range in Tenasserim at 5500 ft., fruit sold as *bunga lawang* in Singapore, of mace-like flavour, and used as a febrifuge.

Large quantities of star-anise are exported from China to England and the Continent, as well as overland to Yarkand and India. Macao, in 1879, shipped 8000 *piculs* (of 133⅓ lb.), the produce of Kwangse. Pakhoi exports paying duty were valued at 9045*l.* in 1879, the average weight of the shipments being 6500 *piculs*. Shanghai, in 1879, despatched 631 *piculs* of whole, and 124 of broken. The approximate London market values are 37–40*s.* a cwt. for common anise, and 75–95*s.* for China star.

The essential oils of anise and star-anise are described on pp. 1416–7.

Capsicums, Chillies, Cayenne-, Red, Pod-, or Guinea-Pepper (Fr., *Piment* or *Corail des Jardins*, *Poivre d'Inde*, or *de Guinée*; Ger., *Spanischer Pfeffer*).—Of the many species or varieties of *Capsicum*, two contribute to the spice found in commerce :—*C. fastigiatum* [*minimum*], occurring wild in S. India, and extensively cultivated in tropical Africa and America; and *C. annuum* [*longum*, *grossum*], of Algeria. Several varieties of the *C. annuum* have little or no pungency; one of these is abundantly grown in Hungary, forming the *paprika* of the Magyárs. Another variety cultivated in Spain is imported into this country in powder for giving to canaries, to improve the colour of their feathers. The smaller varieties (*C. fastigiatum*) are usually known as "chillies" or "bird pepper." The Nepal capsicums, which have an odour and flavour resembling orris-root, are the most esteemed as a condiment. The fruits of the first species are not more than ½–¾ in. long, while those of the second reach 2–3 in. Capsicum pods and the seeds dried and pounded are considerable objects of trade. In 1871, Sierra Leone exported 7258 lb., and Natal, 9072 lb., while Singapore, in the same year, imported 1071 cwt., chiefly from Penang and Pegu. Bombay imported 5567 cwt., principally from the Madras Presidency, in 1872–3, and exported 3323 cwt.

Caraways (Fr., *Fruits* or *Semences de Carvi*; Ger., *Kümmel*).—The mother-plant of caraway "seeds" (*Carum Carvi*) grows in moist meadows, widely throughout Europe and Asia, from Iceland to the Himálayas, and in a prescribed district of N. Africa, partly wild, partly under cultivation. In England, it is found wild in Lincoln, York, and some other shires, and is cultivated with coriander on clay lands in Kent and Essex. It needs much care and diligence, yielding in the 2nd year a crop which is harvested in July, by cutting with a hook at about 1 ft. from the ground, and is ready for threshing a few days later, the produce of "seeds" being 4–8 cwt. an acre. In Germany, the cultivation is largely carried on in Moravia, as well as in Prussia, especially near Halle, and in the districts of Erfurt and Merseburg, the yield from the two latter being stated at 30,000 cwt. yearly. In Holland, quantities are grown in N. Holland, Gelderland, and N. Brabant, the plants being wild in the two latter provinces. The fruits are exported from Finmark (Norway), and from Finland and Russia, the plant growing throughout Continental Scandinavia, Arctic, Central, and S. Russia, and Siberia. Thence it extends into Persia, the Caucasus, Armenia, and the high alpine region of Lahoul, W. Himálaya. It is also found throughout E. France, the Pyrenees, and Spain. The statement that it is much cultivated in Iceland, is open to great doubt. A large variety is grown in isolated districts in Morocco, viz. about El Araiche and around Morocco City. The exports thence were 952 cwt. in 1872; and from Tangier to Great Britain, they were 46 cwt., 37*l.*, in 1878, and 120 cwt., 118*l.*, in 1880. Memel, in 1879, shipped 2057 cwt., 2777*l.* Our total imports in 1870 were 19,160 cwt., mainly from Holland. The kinds distinguished in the London market are English, Dutch, German, and Mogador.

The essential oil of caraway is described on pp. 1418–9.

Cardamoms (Fr., *Cardamomes*; Ger., *Cardamomen*).—There are two varieties of the cardamom plant affording the commercial spice. *Elettaria* [*Alpinia*] *Cardamomum*, growing both wild and cultivated in the moist, shady, mountain forests of N. Canara, Coorg, and the Wynaad, at 2500–5000 ft. elevation, where the mean temperature is 22° (72° F.), and the annual rainfall 121 in.; and var. *β.*, giving longer and larger fruits, found wild in the forests of Central and S. Ceylon. The latter are known in commerce as Ceylon cardamoms. They are about 1–1½ in. long, ½ in. diam.; of a greyish colour, and are not bleached like the ordinary cardamoms. Large quantities of the fruit are collected from wild plants, but cultivation is also extensively carried on, varying considerably in the different districts.

In Travancore, Coorg, and the Wynaad, the plan adopted is as follows. In the dry season, spots are selected on a slope of W. or N. aspect in the shady forest where some of the plants are already growing, and a patch measuring some 250–350 ft. by 30–40 is cleared of underwood in such a situation that it will be covered by felling one of the huge forest trees, whose destruction will admit sun and light. The cardamom plants spring up quasi-spontaneously, and attain a height of 2–3 ft. during the following monsoon, after which, the patch is weeded, fenced, and left for a year. The plants commence to bear about 3½ years after their first appearance, and continue productive for 6–7 years, the yield being 28–48 lb. per annum from an acre of forest containing 4 patches of 484 sq. yd. in area. In Travancore and Cochin, cardamoms are monopolies of the native rajahs. All the produce of the former State is conveyed to the port of Aleppy [Alapalli], where it is sold by auction chiefly to Moplah merchants for distribution over India, and the finest for export to England.

The plant is raised from seed both on the lower range of the Pulney Hills, near Dindigul, at about 5000 ft., and in the betel-nut plantations of N. Canara and W. Mysore. In the former locality, the *sholas*, or forests which are moist all the year round, are cleared of underwood and small trees; the cardamoms are sown, and, when a few inches high, are planted out in ones or twos under the shade of the big trees, requiring 5 years before bearing fruit. In the betel-gardens, the plants derive shade from the palms and plantains, and are fruitful at 3 years.

The cardamom harvest begins in October and continues for 2–3 months. The fruits do not ripen simultaneously, and therefore require much attention in plucking, while it is necessary to guard against their being eaten by snakes, frogs, and squirrels, and to gather them before the capsules have split. For perfection, the fruits require a short drying after collection, either by sun-heat or gentle fire-heat. They are esteemed in proportion to their plumpness and heaviness, and the sound and mature condition of their seeds, which should form about ¾ of the weight. The Indian kind measure $\frac{4}{10}$–$\frac{9}{10}$ in. long, the Ceylon 1–2 in. The approximate London market values are:—Malabar, good, 6*s.*–9*s.* 6*d.* a lb., inferior, 2*s.*–7*s.* 6*d.*; Aleppy, 2–9*s.*; Madras, 1*s.* 6*d.*–7*s.*; Ceylon, 2*s.* 6*d.*–5*s.* 6*d.* In 1872, Bombay exported 1650 cwt., 1055 being for the United Kingdom; and Ceylon, 9273 lb. to the United Kingdom.

Several other kinds of cardamom possess an importance in Asiatic commerce; they are chiefly as follows:—(1) Round or Cluster cardamom (*Amomum Cardamomum*), a native of Cambodia, Siam, Sumatra, and Java, produced in small compact bunches, the fruit being nearly globular and smooth; (2) the Wild, Bastard, or Xanthioid cardamom, or "cardamom seeds," afforded by *A. xanthioides*, a native of Tenasserim and Siam; these are oval and covered with short prickles. These two sorts are the objects of considerable trade between Siam, Singapore, and China, and one of them is probably the kind cultivated by the French settlers in Saigon, where 1350 *piculs* (of 133¾ lb.) were produced in 1880. The shipments from Bangkok in 1871 were 4678 *piculs* (623,733 lb.), all to Singapore and China; and in 1875, 267 *piculs* of "true," and 3267 of "bastard" cardamoms. Hankow imported in 1879, from abroad, 132 *piculs* (of 133⅓ lb.) of superior, 6985*l.*, and 2362 of inferior, 21,732*l.*; and from native ports, 142½ *piculs* of superior, 7534*l.* Shanghai imported in 1879, 327 *piculs* of superior, 3810 of inferior, and 233 of husks. (3) Winged or Bengal cardamom, *morung elachi* or *buro elachi* (*A. aromaticum*), is produced in the Morung Mountains, in about 26° 30′ N. lat. (4) Nepal cardamoms, from *Amomum subulatum*, are grown on well-watered hill-slopes, under shelter of trees, on the frontiers of Nepal, near Darjiling, and exported to other parts of India. (5) Java cardamoms are produced by *A. maximum* in that island; these are of a brown colour, and more or less furnished with winged longitudinal ridges. (6) Korarima cardamoms are yielded by *Amomum Korarima* (*Cardamomum majus*), an undescribed plant indigenous to the whole mountain region of E. Africa, from Uganda to the countries of Tumhé, Guragne, and Shoa, lying S. and S.-E. of Abyssinia. They are carried to Baso (10° N. lat.), and thence to Massowa, for shipment to India and Arabia. They are of a brown colour, 1½–2 in. long, ¾ in. diam. below, oblong, pear-shaped, and slightly furrowed.

The essential oil afforded by cardamoms is described on p. 1419; they are also capable of yielding as much as 10 per cent of a fatty oil.

Cassia (Fr., *Casse*; Ger., *Cassia*).—The bulk of the spice known as cassia, or "Chinese cinnamon" as it is frequently called on the Continent, is produced by an undescribed tree of S. China, chiefly growing in Loting and Luehpo (in Kwangtung province), Taiwao (in Kwangsi), and in Kweichow, and found in about 19° N. lat. in the forests of the Le Ngum valley, on the left bank of the Mekong, near the Annam frontier. The tree is generally referred to as *Cinnamomum* [*Cassia*] *aromaticum*. It is said to grow with little attention in situations unsuited to other crops. The bark of the tree, forming "cassia lignea," occurs in small bundles about 1 ft. long and 1 lb. in weight, bound up with split bamboo. It has been stripped off the tree by running a knife along each side of the branch, and gradually loosening it; it is then allowed to lie for 24 hours, undergoing a sort of fermentation which permits the epidermis to be easily scraped off, the bark soon drying into the form in which it appears in the market. The quills bear a close resemblance to cinnamon (see pp. 1805–7), but are less uniform and less carefully prepared. They are thicker and harder than cinnamon, and rarely consist of more than two quills, one rolled in the other. There is no doubt that the powdered bark is very largely substituted for the higher priced cinnamon, discrimination between them being a matter of some difficulty. The most reliable tests yet made known for their distinction are given by Hehner, in a paper read before the Society of Public Analysts, Nov. 19, 1879, the main deductions from his observations being:—(1) The proportion of ash in cinnamon is pretty constant (4·59–4·78 per cent.), cassia lignea giving much less (1·84), and cassia vera nearly the same as cinnamon (say 4·08); (2) the amount of ash soluble in water is 25·04–28·98 per cent. in whole cinnamon, about 18 in chips, 8-15 in cassia vera, and 26–40 in cassia lignea; (3) the proportion of oxide of manganese is never more than 1 per cent. (0·13–0·97) in cinnamon, but over 1 (1·13–1·53) in cassia vera, and 3·65–5·11 in cassia lignea; (4) the cinnamon ash is always white, or nearly so, while both the cassia ashes are grey or brown, and yield abundance of chlorine on heating with hydrochloric acid. The young branches of the tree affording cassia lignea are collected and tied up in fagots, constituting cassia twigs, which are a large article of local commerce. The immature fruits of the same tree are believed to form the cassia buds of English trade. Cassia vera or wild cassia is an inferior kind of cassia lignea. The approximate London market values of the spice are:—Lignea, 36–60*s.* a cwt.; vera, 22–46*s.*; buds, 49–72*s.* Our imports of cassia bark (lignea) fluctuated from 1,408,021 lb. 1856, to 283,869 in 1861, 1,117,909 in 1865, 349,349 in 1866, and 875,991 in 1870; since then, it has not been specified in the Returns. In 1878, London received 3,500,000 lb. Hamburg usually imports about 2,000,000 lb. annually direct from China, besides large quantities indirectly. The shipments from Canton, whence it is chiefly exported, had grown from 13,800 *piculs* (of 133⅓ lb.) in 1864, to 96,778¼ *piculs* in 1879. In the same year, Pakhoi despatched 3018*l.* worth; and Shanghai, 124⅓ *piculs* of buds, 3234½ *piculs* of lignea, and 4467¼ *piculs* of twigs. The twigs are mainly an article of local consumption. In 1872, Canton shipped 456,533 lb. of them to other Chinese ports. In 1879, Hankow imported from foreign ports, 1387 *piculs* of lignea, 8773*l.*; and from native ports, 128¾ *piculs* of buds, 381*l.*, 1182½ of lignea, 7479*l.*, and 3990¾ of twigs, 3442*l.* The trade in buds has decreased, the exports from Canton having fallen from 400 *piculs* in 1848, to 233 in 1866, and 165 in 1867. Our imports of them in 1870 were 29,321 lb.; Hamburg received 1324 cwt. in 1876.

Several other non-Cingalese species of *Cinnamomum* afford kinds of cassia bark in their respective localities. In the Khasia mountains of E. Bengal, the barks of three species (*C. obtusifolium*, *C. pauciflorum*, and *C. Tamala*), growing wild at 1000–4000 ft., have recently been collected and brought down to Calcutta. At least part of the cassia bark of S. India is produced by *C. iners*, possibly only a variety of the true cinnamon (*C. zeylanicum*), found in India, Ceylon, Tavoy, and the Indian Archipelago; the fruits are also gathered in some districts of S. India, but are much inferior to Chinese buds. *C. Tamala* extends into Silhet, Sikkim, Nepal, Kumaon, and even Australia. The Archipelago produces two species, *C. Cassia* and *C. Burmanni* var. *a. chinense*, both said to be cultivated in Java. Padang (Sumatra) exported 6127 *piculs* (817,066 lb.) of the bark in 1871; and Cadiz imported 93,000 lb. from the Philippines in the same year.

According to Low, the *kulit lawang* of Borneo is the aromatic bark of a wild species of "cinnamon," and is produced in abundance in all parts of the island. It much resembles the true cinnamon of Ceylon. A recent writer on the Indian Archipelago (Moore) states that "cinnamon" is the most costly product of Cochin China, and is an uncultivated article. It has a very pungent taste, and is far more aromatic than that of Ceylon. There are several qualities of it, some of which bear a most exorbitant price, and are solely appropriated for the royal use. The outer rind is never removed from it, and it is consequently much thicker than Ceylon cinnamon. It is in high demand among the Chinese, who export large quantities, and prefer it to the best cinnamon of Ceylon. Possibly it is this particular kind which is meant in the Consular Returns for Shanghai for 1879, where an export of 50½ *piculs* (of 133⅓ lb.) of "cinnamon" is stated, in addition to the figures relating to cassia. Hanbury and Flückiger doubtfully refer this thick "cinnamon," or more properly cassia, to *C. Cassia* and *C. Burmanni* var. *a. chinense.*

The essential oil of cassia is described on p. 1419.

Chiretta or Chirayta.—This condiment consists of the entire plant of *Ophelia Chirata* [*Gentiana Chirayita*] collected when the capsules are fully formed, and tied up in flattish fagots, 3 ft. long and weighing 1½–2 lb., with bamboo slips. The plant inhabits the mountainous districts of N. India, from Simla through Kumaon to the Murung district in S.-E. Nepal. It is much used in India, and somewhat in England as a tonic bitter, and substitute for gentian in cattle-foods. An inferior variety, *Ophelia angustifolia*, is sometimes mixed with this drug as found in English commerce. It is less bitter, and is distinguishable by the absence of pith, and by the more woody stem.

Cinnamon (Fr., *Cannelle de Ceylan*; Ger., *Zimmt*, *Ceylon Zimmt*, *Kaneel*).—True cinnamon, with which cassia is often confounded, is produced by *Cinnamomum zeylanicum*, a small evergreen tree of many varieties, distributed through the forests of Ceylon up to 3000 and even 8000 ft. The quality of the bark varies exceedingly with local conditions, some being so inferior as to be collected only for purposes of adulteration. The culture of the best kind seems to be restricted to a strip of country 12–15 miles broad on the S.-W. coast of Ceylon, between Negumbo, Colombo, and Matura, up to an elevation of 1500 ft. A sandy soil is generally selected, but others may be chosen, such as a mixture of sandy with red soil, free from quartz, gravel, or rock; also red and dark-brown soils. Such land in a flat country is preferable to hilly spots. A rocky and stony subsoil is not adapted, as the trees would neither grow fast, nor yield a remunerative return. In making a plantation, the whole of the ground should be cleared, leaving a few trees 50–60 ft. apart. The felled trees should be well lopped, burned, and cleared away. The stumps and roots, after burning, may be allowed to remain, in order to save expense of carriage, merely observing some degree of order in their disposition, by forming regular rows. Holes are dug 8–10 ft. apart and 1 ft. sq.; the distance between the plants depends upon the nature of the soil: the poorer the soil, the nearer should the trees be planted, and *vice versâ*. Should the holes be intended for cinnamon roots, or stumps, the latter must be carefully removed with as much earth as can be carried up with them, and placed in the holes, taking care not to return the earth removed originally in digging the holes, but filling them with the soil scraped from the surface, which has been previously burned, exposed, and formed into manure. Should no rain fall after placing the roots in the holes, the stumps are well covered, and watered morning and evening, until the sprouts shoot out fresh buds, which will be in a fortnight or so from the time of transplanting; watering may then be discontinued. In a month, the new shoots will be 3–4 in. high, much depending upon the weather. If the holes be intended for young plants or seedlings, the latter are removed with boles of earth from the nurseries, and placed in the holes, taking the same care as with the stumps, both in watering and covering, in the event of its being dry weather. The coverings should not be removed until the plant throws out a new pair of leaves from the buds, which is a sign of their having taken root. When a plantation is formed of old stumps, all the branches are cut down to within 6 in. from the ground; this should be done with one stroke of a sharp instrument, in order to avoid the splitting of the stem. From these stumps, cinnamon may be cut and peeled in 12–18 months from the time of transplanting. From seedlings, no crop can be expected before 2–3 years from the date of the transplanting, when there will be but single trees. These, when cut down as already observed to 4–6 in. above the ground, ought to be covered with fresh earth gathered from the space between the rows, and formed in a heap around the base. The next crop will be 3–4 times as much as the first, from the number of sprouts the stem will throw out, and so on every year, the crop increasing according to the number of sprouts each stem will throw out yearly from the cuttings. In the course of 7–8 years, the space left between the rows will only admit the peelers and weeders, as the branches from opposite bushes will almost touch each other. The plantation must be kept clean and free from weeds. Cinnamon requires no manuring; but when weeding, the roots of the bushes should be covered and heaped up with the surface soil, this being done as soon as the cinnamon sticks are removed for peeling. The plantation requires weeding 3–4 times a year during the first 2–3 years, then twice a year will answer the purpose.

For the nursery, a space of ground is selected in rich soil free from stones. The whole brushwood is cleared, leaving only the large trees for shade; all stumps, stones, and roots are removed, and the place is well dug 6–8 in. deep, and formed into long beds 3–4 ft. wide; the seeds are sown 9–12 in. apart, and shaded at 8–12 in. above the ground by a *pandal* of leaves; they are watered on alternate days until they have one pair of leaves, and the watering is continued in very dry weather; but the shade is not removed until the plants are 6–8 in. high, and can bear the sun. These seedlings will be ready for transplanting 3 months after the time when they were sown. Nurseries are made just before the close of the year. When this is done first, the land is prepared during the dry season, from December to March, both inclusive. April sets in with heavy rain generally in Ceylon, and the weather continues wet till September–October. The cinnamon seeds are gathered when fully ripe, and heaped up in a shady place; the outside red pulp then rots and turns quite black, allowing the seeds to be trampled out or otherwise freed from the decomposed pulp; the seeds are well washed in water (just as is done to cherry coffee, before making into parchment in the white shell, see pp. 702–3), and dried in the air without exposure to the sun. Seeds that float on the surface of the water should be rejected. The quality of the bark depends upon its situation on the branch: that peeled from the middle of the bush or branch is the best or "1st" sort; that taken from the upper end, the "2nd"; while that obtained from the base of the branch, or the thickest end, is called "3rd" sort. The peeling process commences early in May, and continues until late in October. When a Chilaw perceives a shoot of a proper growth, he strikes a small bill-hook (*catty*) obliquely into the shoot, and gently opens the gash to discover whether the bark separates freely from the wood; should this not be the case, he leaves the sucker for a future time. Some shoots never arrive at a fit state for decortication. Those which are cut are usually ½–⅝ in. diam., and 3–5 ft. long. They are tied in bundles, and carried to sheds appropriated to the preparation of the cinnamon.

Being cleared of small shoots and leaves, two longitudinal slits are made in the bark, which is gradually loosened by the convex side of a peculiar knife (*mama*), and then usually half the circumference of the bark comes off in one entire slip. When the bark adheres firmly to the wood, it is strongly rubbed with the handle of the peeling-knife, until it is disengaged and stripped off. The sections of the bark thus obtained are carefully telescoped one into the other, collected into bundles, and firmly pressed or bound together. In this state, they remain for 24 hours, or more, thereby facilitating the subsequent removal of the cuticle. The interior side of each section of bark is placed on a convex piece of wood, and the epidermis, together with the greenish pulpy matter immediately under it, is carefully scraped off by a curved knife. This is an operation requiring some nicety, for if any of the outer bark be allowed to remain, it gives an unpleasant bitterness to the cinnamon. In a few hours after the removal of the cuticle, the pieces are put one into the other till they form almost solid sticks about 40 in. long. On the first day, they are suspended under shelter upon open flat forms; on the second day, they are placed on wickerwork shelves, and exposed to the sun. When sufficiently dry, they are made up into bundles of about 30 lb. each, which, previous to shipment, are subjected to a process of assortment. For export to Europe, the bark of large shoots or thick branches, producing coarse cinnamon, and that of very young and succulent shoots, possessing little flavour, is rejected, and used for the preparation of the essential oil (see p. 1419).

The cinnamon-gardens of Ceylon had increased from 14,400 acres in 1860–4, to 26,000 in 1878. It is still being extensively planted upon nearly worn-out coffee estates, and upon other land considered unpromising for more valuable crops, and the results are said to be satisfactory. The exports from the island have fluctuated considerably, having been 776,675 lb., 38,833*l.*, in 1864, 2,685,395 lb., 134,270*l.*, in 1869, 1,132,191 lb., 53,077*l.*, in 1874, and 1,665,481 lb., 78,069*l.*, in 1878. The London market values of Ceylon cinnamon are :—1st quality, 1*s.*–3*s.* 6*d.* a lb.; 2nd, 11–28*d.*; 3rd, 7–21*d.*; 4th, 7–18*d.*; chips, 1¼–6½*d.*

The peculiar tendency of cinnamon to deteriorate in new localities, coupled perhaps with the absence of due care and experience, has rendered it impossible to produce the spice equal to the Cingalese article anywhere outside that island. It is most nearly approached by that grown in S. India, known as "Malabar," "Tinnevelly," or "Tellicherry," and valued at 1*s.* 5*d.*–2*s.* 4*d.* a lb. In the Seychelles, are said to exist 2000 acres of cinnamon shrubs, which are utilized solely as firewood. In Dominica also, the plant is found commonly in a wild state. Brazil and French Guiana afford insignificant quantities of a very inferior cinnamon. But Java occupies an important position as a producer of this spice. The culture and preparation do not differ essentially from the methods practised in Ceylon, but the packing is usually effected in wooden cases, and black pepper is said to be sprinkled among it to preserve the flavour. The exports from Java in 1879–80 were :—638 *piculs* (of 135½ lb.) to Holland, and 24 to Australia.

Our imports of cinnamon in 1880 were :—1,377,272 lb., 91,544*l.*, from Ceylon; 189,548 lb., 8213*l.*, from other countries; total, 1,566,820 lb., 99,757*l.* Our re-exports in 1880 were 1,172,166 lb., 78,805*l.*, chiefly to Spain, Germany, Mexico, and Holland.

Other *Cinnamomum spp.*, and the means of distinguishing cinnamon from cassia, are described under the latter (pp. 1804–5).

Cloves (Fr., *Girofles*, *Clous de Girofles*; Ger., *Gewürznelken*).—The name cloves is applied to the dried flower-buds or calyces of *Eugenia caryophyllata* [*Caryophyllus aromaticus*], an evergreen tree of 30–40 ft., indigenous only in the five small islands constituting the Moluccas proper (Tarnati, Tidor, Mortir, Makian, and Bachian), but introduced at various times into, and more or less widely cultivated in, Amboina, Haruku, Saparua, Nusalant, Sumatra, Penang, Malacca, Mascarene Islands, Réunion, Mauritius, Zanzibar, Pemba, Jamaica, Dominica, and French Guiana.

In cultivating cloves, the mother-cloves (fruits) are planted in rich mould about 12 in. apart, screened from the sun, and duly watered. They germinate within 5 weeks, and, when 4 ft. high, are transplanted at distances of 30 ft. There should be a certain amount of sand in the soil to reduce its tenacity, and less manure is required than for nutmegs. The tree naturally selects a volcanic soil, and a sloping position. The yield commences at about the 6th year, and is at its maximum in the 12th year, when the average annual produce may be estimated at 6–7 lb. of marketable fruit from each tree. There is usually a crop every year, but in Sumatra, the trees often bear only twice in 3 years. When past its prime, the tree has a ragged appearance. Its existence in Sumatra is supposed to be limited to a duration of about 20 years, except in very superior soil, when it may perhaps last 24 years; yet in Amboina, it does not bear till the 12th–15th year, and continues prolific to the age of 75–150 years. Hence, it is necessary to plant a succession of seedlings when the old trees have attained their 8th year, this octennial system being adhered to throughout. The slight hold which the trees have upon the soil, renders it very desirable that they should be provided with shelter from strong winds. With this object, the plantations in Sumatra are belted with a double row of *Casuarina littorea* and *Cerbera Manghas.* Similar precautions in Zanzibar and Réunion would probably have mitigated the havoc recently created by hurricanes among their clove-gardens. The harvesting of the flower-buds (cloves) commences immediately they assume a bright-red colour. The best and most usual plan is to pluck them singly by hand, movable stages facilitating the operation in the case of the upper branches. Sometimes, however, they are beaten off by long bamboos, and caught in cloths spread below. The plucked cloves undergo a process of drying, which confers a brown hue, and prepares them for packing. In Sumatra, simple exposure to the sun for several days on mats is the common method; but elsewhere they are occasionally also smoked on hurdles covered with matting near a slow wood fire; and very rarely they are scalded in hot water before smoking. They are ready for packing when they break easily between the fingers.

The production of cloves fluctuates enormously. The Moluccas, or rather the four of them where the tree is cultivated (Amboina, Haruku, Saparua, and Nusalant), produced 869,727 Amsterdam lb. (of 2·2 lb.) in 1846, but only 89,923 in 1849; in 1854, Nusalant harvested 120,283 Amsterdam lb. from 13,042 trees (an average of 9 lb. a tree), Saparua 181,137 from 29,732 trees, Haruku 38,803, Amboina 170,689; total, 510,912 Amsterdam lb. Java exported only 92 *piculs* (of 135½ lb.) in 1879–80; but in 1878–9, the figures were 1614 to Holland, 5 to Sweden, 3 to America, and 1237 to Singapore, total 2859 *piculs*. Of late years, the islands of Zanzibar and Pemba on the E. African coast, have been the chief producers of cloves, yielding a maximum annual crop of 10½ million lb. before the disastrous hurricane of 1872. The clove-gardens of Pemba, situated mostly on the W. side of the island, escaped the destruction which befel the larger island. The exports from these two islands go largely to Bombay, also direct to America and Hamburg, smaller quantities reaching the Red Sea ports by native craft. For European and American markets, the packages used are mat bags made of split coco-nut leaves; for native ports, simply raw hides. The Bombay imports were 45,642 cwt. in 1869–70, 20,968 in 1870–1, 43,891 in 1871–2, 25,185 in 1872–3. Réunion in 1825–49 produced yearly as much as 800,000 *kilo.* (of 2·2 lb.), but has recently suffered much from hurricanes; the crop of 1879 was destroyed by a cyclone, and the exports for 1879 (8777 *kilo.*) were merely re-exports from St. Marie de Madagascar. In Jamaica and Dominica, cloves flourish remarkably, and are eminently suited for cultivation with nutmegs by small proprietors on the hills. Our imports in 1870 were 1,089,667 lb., 16,374*l.*; there are no specific returns since. We received 3271 cwt. from Bombay in 1872–3. Hankow, in 1879, imported 256½ *piculs* (of 133⅓ lb.) of cloves, 4056*l.*; and 30 *piculs* of mother-cloves, 438*l.* The cloves of commerce vary in plumpness, brightness of tint, and yield of essential oil. The values of the chief kinds met with in the London market are:—Penang, 20–29*d.* a lb.; Amboina, 16–23*d.*; Zanzibar, 14–19*d.*

Clove-stalks, the *vikunia* of the natives, are largely shipped from Zanzibar, and used in the manufacture of mixed spice and for adulterating ground cloves. They yield 4–6½ per cent. of volatile oil. Mother-cloves or fruits are also exported, probably for a similar purpose. In one drug sale in 1873, 4200 packages of the former were sold at 3–4*d.* a lb., and 1050 bags of the latter at 2–3*d.* a lb. The microscope will reveal the stone-cells of the stalks and the large starch-granules of the fruit, as well as both stone-cells and starch-granules if pimento has been fraudulently added.

The essential oil of cloves is described on p. 1420.

In Brazil, the flower-buds of *Dicypellium caryophyllatum*, whose bark furnishes clove cassia, are used as substitutes for true cloves.

Coriander (Fr. *Coriandre*; Ger. *Koriander*).—Coriander-seeds are the produce of *Coriandrum sativum*, a small plant now found growing as a cornfield weed in many temperate and tropical countries. It is cultivated in the E. counties of England, especially Essex, and in various parts of the Continent; it is also produced in India and N. Africa. In the Dutch E. Indies, a larger and more oval variety is met with. In England, under the name of "col," it is sometimes sown with caraway, and gathered in the first year, while the caraway is left on the ground till the following season. The seedlings are hoed out so as to leave rows 10–12 in. apart. Harvesting is performed with sickles, and the dry seed is threshed out on a cloth in the field, an average crop being 15 cwt. an acre on the best land. In 1872–3, Sind exported 948 cwt., and Bombay 619 cwt., while Calcutta shipped 16,347 cwt. in 1870–1. Corianders are mostly used for flavouring gin, and in the manufacture of curry-powder.

The essential oil is described on p. 1420.

Cumin. See Drugs, pp. 809–10.

Galangal or Galingale (Fr., *Galanga*; Ger., *Galgant*).—The galangal root now met with in European commerce is the rhizome of the lesser or Chinese plant (*Alpinia officinarum*), cultivated in Hainan Island, S. China, and probably also in some of the adjacent mainland provinces, while the greater or Java galangal (*A. Galanga*) is rarely seen amongst us. In E. Europe, particularly Russia, it is used as a spice, for flavouring tea and liqueurs, and in cattle medicine. Shanghai exported 370,800 lb., value 3046*l.*, in 1869; and Kiungchow, 2113 *piculs* (281,733 lb.) in 1877, and 5661½ *piculs*, 2194*l.* in 1879, the latter stated officially to come entirely from the mainland opposite. It is of a dark-brown colour, and powerfully pungent.

The essential oil is described on p. 1421.

Gentian (Fr., *Gentiane*; Ger., *Enzian*).—Gentian is the dried root of *G. lutea*, a native of open grassy places on the mountains of Central and S. Europe, as far north as the Suabian Alps, near Würzburg. The roots of several other species are sometimes collected and mixed with it, viz.:—(1) *G. purpurea*, found in meadows on the Apennines, in Savoy, Switzerland, Transylvania, and S.-W. Norway, and a variety in Kamschatka; (2) *G. punctata*, indigenous to the Alps of S.-E. France, Savoy, S. Switzerland, extending E. to Austria, Hungary, and Roumelia; (3) *G. pannonica*, met with only on the mountains of Austro-Hungary. *G. Catesbœi* [*Saponaria*] is gathered for home consumption in the United States. The roots are collected and dried. Our supplies come mostly from Germany, but partly also from Marseilles. Our imports in 1870 were 1100 cwt. In England, it is used medicinally (see p. 811), but principally as an ingredient of cattle-foods. In Bavaria and Switzerland, advantage is taken of its 12–15 per cent. of uncrystallizable sugar to make from it a liquor known as *Enziangeist* or "gentian-spirit."

Ginger (Fr., *Gingembre*; Ger., *Ingwer*).—Ginger is the dried rhizome, either scraped or unscraped, of *Zingiber officinale* [*Amomum Zingiber*], a reed-like plant indigenous to Asia, and universally cultivated in the warmer parts, but not known wild; now to be found also in the W. Indies, S. America, Tropical W. Africa, and Queensland.

In Jamaica, propagation is effected by division of the root, the pieces being planted in well cleared and trenched land in March–April, flowering in September, and fading towards the end of the year; when the stems are quite withered, generally about January, the roots are dug up, picked, cleaned, gradually scalded in boiling water, sun-dried for several days, and packed, forming "hands" or "races" of so-called "coated" (i. e. not deprived of epidermis) ginger. Jamaica had 227 acres under this crop in 1875–6, and 144 in 1877–8. The exports from the island were 1,261,873 lb. in 1869, only 599,766 in 1871–2, 1,613,764 in 1875–6, and 908,603 in 1877–8. The London market values of Jamaica ginger are approximately 4½–12*l.* a cwt. for fine, and 2¼–5¼*l.* for ordinary to good. Formerly Barbados and Hayti used to grow ginger in considerable quantity; but the latter now exports none, and the shipments of green ginger from the former were valued at only 56*l.* in 1877, and 41*l.* in 1878. Our imports from the British W. Indies were 15,594 cwt. in 1876.

Little is known about the production of ginger in Sierra Leone. In 1868, the value of the export was 18,917*l.*; in 1869, 14,008*l.* Our direct imports were 6612 cwt. in 1878, and 11,951 in 1879. About half the produce comes to England, and the other half goes to America. The London market value of African ginger is only about 18–25*s.* a cwt.

The cultivation of ginger in India extends from the Himálayas to Cape Comorin. In the Hill States, the best "races" of the previous year are smeared with cow-dung and placed in a corner where they will not dry up. After the first rain, the land is ploughed 2–3 times, and divided into little beds which will shed the water readily. Root-sections are then planted 3 in. deep and 9 in. apart, and covered with dead leaves and ½ in. of manure. Watering is resorted to in the dries. When the plants are about 2 ft. high, the rhizomes are dug up, buried for a month, sun-dried for a day, and are ready for use. To get it into *sonth*, or keeping condition, the fresh rhizomes are shaken in a basket for 2 hours daily for 3 days, then sun-dried for 8 days, and again shaken. Thus the outer skin is removed, and 2 days' further drying finish it for the market. In Dacca, the natives cleanse the roots by boiling lime-water. In Mysore, a red soil free from stones is considered best; between 11 April and 11 May, the ground is hoed, and made into ridges 18 in. broad, 18 in. high, and 18 in. apart, with perpendicular sides; two rows of cuttings are put into each ridge, slightly covered with earth, and protected by a screen of bushes. Between mid-June and mid-July, the shoots appear, and 10 days later the bushes are replaced by small twigs, and weeding is done by hand. About mid-December to mid-January, the roots are fit for pulling. Those intended for replanting are mixed with a little red mud, and immediately buried in a pit; those intended for sale are deprived of the outer skin by scraping with a knife, sprinkled with the ashes of burnt cow-dung, and dried on mats for 8–10 days. Our imports of E. Indian ginger were 7472 cwt. from Bombay and Sind in 1877, increased to 25,781 cwt. in 1879; 7202 cwt. from Madras in 1877; 16,470 cwt. from Bengal in 1878. The London market values are about 16–22*s.* a cwt. for Bengal, and 23–125*s.* for Cochin.

Much ginger is grown in China, and considerable quantities of the young succulent rhizomes preserved in syrup are sent to this country. Our imports were 9372 cwt., 25,722*l.*, in 1872, and 6996 cwt., 19,894*l.*, in 1875. The Venezuelan port of Ciudad Bolivar shipped 450 lb. to New York in 1878; and Panama exported 98*l.* worth to the United States in 1879.

"Scraped" or "uncoated" (decorticated) ginger is often bleached by subjection to the fumes of burning sulphur, or by immersion in chloride of lime solution, while much is washed over with either sulphate or carbonate of lime. Our total imports in 1880 were from:—Bombay and Sind, 23,249 cwt., 45,828*l.*; Madras, 12,492 cwt., 25,460*l.*; British W. Indies, 5639 cwt., 28,624*l.*; Bengal and Burma, 3617 cwt., 3713*l.*; W. Africa, 3142 cwt., 3000*l.*; other countries, 1823 cwt., 2920*l.*; total, 49,962 cwt., 109,545*l.* The total figure for 1876 was 62,164 cwt. Our re-exports in 1880 were 18,086 cwt., 32,152*l.*, chiefly to Germany, the United States, and Australia.

The essential oil is described on p. 1421.

Mustard (Fr., *Moutarde*; Ger., *Senf*).—Black mustard is the seed of *Brassica* [*Sinapis*] *nigra* and white mustard that of *B.* [*S.*] *alba*, while Indian mustard, brown mustard, or *rai* is afforded by *B.* [*S.*] *juncea*, and is sometimes offered in London sales for black mustard. *S. glauca* and *S. ramosa* also yield a white mustard-seed in India.

The first species is found wild in all but the most northern parts of Europe, as well as in N. Africa, Asia Minor, Mesopotamia, the Caucasus, W. India, S. Siberia, China, and naturalized in N. and S. America. It is cultivated extensively in Alsace, Bohemia, Holland, Italy, and on the richest alluvial soils in England, notably in Lincolnshire and Yorkshire. The great aim of the grower is to produce reddish-brown seed, without any intermixture of grey, which is attributed to rain during the ripening, and greatly lowers the value of the parcel. The crop requires very little tillage. A shallow furrow is ploughed, and the seed is sown broadcast, at the rate of 1 bush. an acre, in April, the harvest taking place in June–July following. The land is generally sufficiently seeded to produce a 2nd crop, which is sometimes gathered within the same year. A yield of 40 bush. an acre is not uncommon. The French departments of Nord, Pas de Calais, Bas-Rhin, and Charente annually produce about 650 tons, value 6000*l.*, while the whole production of France in 1867 was stated at 3000 tons.

The second (white) species belongs rather to S. Europe and W. Asia, but its cultivation is extending in England, where it is grown as an agricultural crop in Essex and Cambridgeshire. It is much less remunerative than black mustard.

The third species is extensively cultivated in India, Central Africa, and other tropical countries. It flourishes particularly well in the saline soils of S. Russia and the steppes lying N.-E. of the Caspian, some 800 tons of seed being annually prepared for table at Sarepta, in the government of Saratov.

The mustard flour which constitutes the domestic spice is prepared from the seeds crushed between rollers, pounded, sifted, and re-sifted into 3 qualities, "superfine," "fine," and "seconds." Only the seeds of the black and white species are supposed to be employed; but it is exceedingly probable that much of the third kind finds its way into the composition, as flour, turmeric, and capsicums are known to do in the lower grades of the article. Characteristic tests by which white and black mustard-seeds may be distinguished are:—(*a*) The aqueous extract of white mustard soon acquires a powerful odour of sulphuretted hydrogen, while the black smells only of the pungent oil; (*b*) the aqueous extract of the former is coloured deep blood-red by ferric chloride solution.

British India exported 1418 tons of mustard-seed in 1871–2, 790 tons going to the United Kingdom, and 516 to France; in 1876, the total figure was 12,770 cwt.; in 1879, only 5016 cwt. Nicolaieff (Russia) exported 498 quarters (of 8 bush.) in 1879.

The fixed and volatile oils of mustard-seed are described respectively on pp. 1396, 1424.

Nutmegs and Mace (Fr., *Muscades et Macis*; Ger., *Muskatnüsse und Muskatblüthe*).—The fruit of *Myristica fragrans* [*moschata, officinalis*], somewhat resembling a small round pear, contains a single seed, the kernel or nucleus of which forms the "nutmeg" of commerce, while its fleshy crimson envelope (*arillus*) is called "mace." The tree is a bushy evergreen of 40–50 ft., found wild in the Banda Islands, Damma, Amboina, Ceram, Bouro, Gilolo (Halmahera), the W. peninsula of New Guinea, and in many neighbouring islands, but not indigenous westward of these, nor to the Philippines. It has been introduced with varying success into Bencoolen (W. Sumatra), Malacca, Bengal, Singapore, Penang, Brazil, the W. Indies, French Guiana, and Réunion; but the Banda Isles remain the chief nutmeg-garden of the world. Of these islands, three are planted with the trees, viz. the Great Banda or Lonthoir, Banda Neira, and Pulo Aai. There are in all 34 parks, containing 319,804 bearing trees. The total produce from these yearly is about 4000 *piculs* (of 139½ lb.) of nutmegs, and 1000 of mace; this gives little more than 1½ *catti* (of 1·39 lb.) of spice for each tree per annum, but then a very large proportion of the produce is lost from the following causes: much cannot be collected from the height of the trees, and the inaccessible places in which hundreds of them are placed, and much is lost by wind-falls; a large pigeon called *walur* feeds extensively upon the fruit, and ejects it after digesting the mace; besides these, field-rats eat the nuts. The distribution amongst the islands is in the following proportions: Great Banda, 25 parks; Neira, 3 parks; Pulo Aai, 6 parks. The chief labour is performed by convicts furnished by the Dutch Government, there being no indigenous population in Banda.

The only attempt at cultivation is the cutting close with long knives the ferns and grass below the trees. There does not appear to be that tendency to the growth of weeds and underwood that exists so strongly in the Straits, to the great detriment of the planters. No manure or artificial stimulus is used; the plants deposited abundantly by the pigeons are merely taken up and stuck in wherever a vacancy occurs, therefore no regularity is observed. In some places, clumps of trees are growing together not more than 10–12 ft. apart, all growing without exception under the shade of the *canari* (*Canarium commune*). The nutmeg cannot be said to be cultivated in Banda: it is merely collected. It has occupied its present position there from time immemorial.

With regard to the differences that exist between the Banda trees and those of the Straits, the first remarkable feature is their respective heights. The tree of the Straits is a mere shrub compared with that of Banda, where 50–60 ft. is no uncommon size. It would appear that the shading is overdone in the Straits, at the same time, owing to the strong winds that constantly prevail, the tree needs shelter of some description. The tree as a general rule does not bear fruit before the 8th or 9th year, and is not considered in its prime until about 25 years old; it is said to bear well up to 60 years, and even longer. The male tree is much shorter lived than the fruit-bearing one. The parkineers in the Bandas do not estimate the proportion of males above 2 per cent.; if this be the case, there are far too great a number in the Straits plantations. With respect to the proportion of males and females yielded by a given number of planted seeds, the parkineers say they never get more than 30 per cent. of males, and seldom so many; this again is far better than Straits planters can boast of. The Banda fruit hangs upon longer and more slender stalks than the Straits, the skin is more free from all blemish, more thin relatively to the fruit, and of more uniform proportion. The black spot or gangrene of the outer covering exists among the Banda plantations, but in so slight a degree that but little account is taken of it. It is caused by an insect depositing its larvæ in the husk; they feed on the saccharine matter of the outer covering, until it bursts, when they make their way into the soft nut itself, and become the small weevil so well known to all planters. The Banda nuts frequently split before maturity, as in the Straits; this is produced by similar causes,—cold, damp weather, and sudden changes of temperature. The Banda trees bear more or less every month throughout the year, but there are four months in which the crop is four or five times its usual quantity, these are May, June, September, and October. The Banda method of collecting the fruit is far better than that adopted in the Straits. They use neatly made oval baskets of bamboo, open for half their length on the upper side, with a couple of prongs projecting from the top; these seize the fruit-stalk, and, by a gentle pull, the nut falls into the basket, which is capable of containing three or four nutmegs. Thus the mace is not spoiled or bruised by falling on the ground, and there is no searching about the grass for the escaped nut.

The Banda manner of breaking them when dried is also superior. This is done by spreading them on a sort of drumhead, and striking them with flat pieces of board. Several are cracked at each stroke, swept off, and resupplied as fast by a man standing alongside. One man in this way will break more nuts without injury than half a dozen men after the Straits fashion. Women and children are employed in the collection of the produce, which is brought in twice a day. The mace is removed by scraping with large knives from the base, and is probably not a little injured by the operation. The plan of removing it by the hand from the apex is decidedly preferable, as the interlacings of the mace are thus freed, and the blade is better expanded. In Banda, the mace is dried in the sun, and delivered monthly at the Government godowns; the nuts are smoked, in the usual Straits fashion, by slow wood fires, for three months, and delivered quarterly. The mace, when received, is divided into three qualities, and packed in casks containing about 280 lb.; in packing, very slight pressure is used, such as a man standing in the cask and treading down the spice as it is filled in. The nuts, when broken, are packed in wooden bins, filled up with lime and water to the consistency of mortar, where they are allowed to remain for three months, the bins being carefully closed and marked. At the expiration of three months, they are taken out, sorted into three qualities, and packed in casks similar to those used for the mace; these casks are all made of the best Java teak. The refuse nuts are ground down to a fine powder, and converted into "nutmeg-butter," by steaming them over large caldrons for 5 or 6 hours, and compressing the warm mass, packed in bags, between powerful wedges, when a brownish-coloured fluid runs out. This on cooling becomes of a saponaceous appearance and consistence, and is the "nutmeg-butter" or "mace-oil" of commerce. It is further described under Vegetable Fixed Oils, pp. 1396–7.

It should be observed that the Banda method of breaking and liming the nuts, which originated with the Dutch policy of monopolizing the culture by destroying the vitality of the exported nuts, is still widely persisted in, and even necessary to suit the prejudices of certain markets. But our planters in Bencoolen adopted a much simpler plan, and one which did not entail the spoiling of a large proportion of the nuts. It consists in exposing the nuts on frames to the gentle heat of a smouldering fire, with proper ventilation, for 2 months, turning them every 2nd or 3rd day; the shells are then cracked by a wooden mallet, and the assorted nuts are rubbed over with dry lime. Even dry liming is said to be unnecessary, as the nuts keep well in their shells, and are thus imported into Chinese markets; but the weight of the shells adds a third to the cost of freight, which is important in long transport.

The Banda Isles remain the chief source of nutmegs and mace, despite all attempts to establish the culture elsewhere, and the figures show a continuous increase in the exports. The shipments from Java of Banda produce in 1878–9 were:—Nutmegs: 10,475 *piculs* (of 135½ lb.) and 7 cases to

Holland, 266 *piculs* to America, 302 *piculs* to Singapore, 78 *piculs* and 11 cases to Port Said, 54 *piculs* to France, 9 *piculs* to England; mace: 2832 *piculs* and 26 cases to Holland, 18 *piculs* to England, 14 *piculs* to Singapore, 10 *piculs* and 6 cases to Port Said. In 1879–80, the figures were:—Nutmegs: 5216 *piculs* to Holland, 61 to France, 1130 to America, 31 to Australia, 777 to Singapore, total, 7215; mace: 1902 *piculs* to Holland, 103 to America, 4 to Australia, 23 to Singapore, total, 2032. The exports from Penang in decennial periods were:—1840, 598 *piculs* (of 133⅓ lb.) nutmegs, 159 of mace; 1850, 2086 of nutmegs, 656 of mace; 1860, 6421 of nutmegs, 2094 of mace. Penang nutmegs have never been limed. Singapore, in 1848, had 1190 acres under nutmegs, containing 71,400 trees, and producing 624 cwt. of nutmegs and 156 of mace. The whole export from the Straits in 1867 was 485,123 cwt. nutmegs, 50,559*l.*, and 5416 cwt. mace, 7354*l.*; the combined total in 1877 was 5323 *piculs* (of 133⅓ lb.); in later years, the figures include all spices except pepper. The nutmeg parks of the Straits have never recovered from the disastrous effects of a blight which attacked them in 1857. The exports from Sumatra were 1952 *piculs* of nutmegs and 403 of mace in 1872; and 2237 of nutmegs and 568 of mace in 1873. The port of Padang alone shipped 284 *piculs* of nutmegs and 28 of mace in 1874; and a total of 2766 *piculs* in 1871. The French island of Réunion exported 5000 lb. of nutmegs and 900 of mace in 1864, and more in 1871, but the culture is declining. The tree succeeds well in the W. Indies, and numbers are to be found under semi-cultivation in Jamaica, Dominica, and Grenada.

Our annual imports of nutmegs amount to 400,000–800,000 lb.; and of mace, 60,000–80,000 lb. The London market values of nutmegs vary with their size, as follows:—78–60 to the lb., 3*s.* 5*d.*–5*s.* a lb.; 90–80, 2*s.* 10*d.*–3*s.* 7*d.*; 132–95, 1*s.* 10*d.*–2*s.* 11*d.* The approximate price of mace is 1*s.*–3*s.* a lb. for 1st quality, and 1*s.*–1*s.* 8*d.* for 2nd and inferior.

The fixed and volatile oils of nutmegs and mace are described respectively on pp. 1396–7, 1424.

Other so-called "nutmegs" which figure very rarely or not at all in commerce are as follows:—American, Jamaican, or calabash (*Monodora Myristica*); Brazilian (*Cryptocarya moschata*); Californian or stinking (*Torreya Myristica*); Madagascar or Clove (*Agathophyllum aromaticum*); long, male, or wild (*Myristica tomentosa* and *M. fatua*), sometimes imported; Peruvian (*Laurelia sempervirens*), used as a spice in Peru; plume (*Atherosperma moschata*); Santa Fé (*Myristica Otoba*), edible.

Pepper (Fr., *Poivre*; Ger., *Pfeffer*).—The name "pepper" is somewhat widely applied. The so-called "Cayenne-" or "red pepper" has been described under Capsicums (see p. 1803). Two species of *Piper* will be found under Drugs, viz. Cubebs (p. 809), and Matico (p. 818); a third falls within the range of the articles on Drugs (Kava-kava, p. 815) and Narcotics (Ava, p. 1305); and two others are dealt with under Narcotics—Betel-pepper, p. 1305. There remain for description as spices, the common black pepper, white pepper, long pepper, and Ashantee pepper.

1. *Black Pepper.*—The plant (*Piper nigrum*) affording black pepper is a perennial climbing shrub, indigenous to the forests of Travancore and Malabar, and cultivated also in Sumatra, Java, Borneo, the Malay Peninsula, Siam, the Philippines, and the W. Indies. Several accounts have been published of the cultivation and harvesting of black pepper; they differ mainly in minor details, and may be summarized as follows.

Where pepper-vines are found already growing, the forest is cleared of underwood, and sufficient trees only are left to provide shade, while permitting free ventilation, 6 ft. apart being considered a proper distance. The vines are trained up to the nearest trees, which are preferably 8–12 in. diam., for convenience in climbing when harvesting the fruit, all kinds of trees being apparently availed of indiscriminately. The root of the vine is manured with a heap of leaves, and the shoots are trained up twice annually. The vines live about 30 years, and are then replaced by others found growing wild around, or systematically planted. The pepper obtained from spontaneous plants is said to quite equal that grown in gardens, while the care necessary is almost nominal. A very wasteful plan sometimes adopted for manuring these natural pepper-plantations consists in setting fire to the trunks of very large trees, which are thus killed, and soon devoured by insects, becoming a heap of rotten dust, which gets washed by the rain around the roots of the vines.

In commencing a new plantation where vines are not to be found growing spontaneously, the first consideration is choice of site. Preference is to be given to level ground bordering rivers or streams, but not subject to inundation; slopes are to be avoided, unless very gentle; and plains will require deep ploughing and much manure. Propagation may be from cuttings and suckers, or from seed. The plants raised by the latter means are said to yield for 14 years, while those from the former are only fruitful for 7 years, but their crops are superior in both quantity and quality, consequently the planting of suckers or cuttings is most generally adopted. The next consideration will be the kind of tree to plant as a support and shade for the vines. Where trees are growing on the ground to be planted with pepper, preference is given to the mango (*Mangifera indica*), whose fruit is not injured by the development of the pepper-vine; failing this, recourse may be had to the jack (*Artocarpus integrifolia*), whose fruit, however, is said to be diminished in quantity and injured in quality by the presence of the pepper. When it is necessary to plant trees, choice is made of the

Erythrina indica, as a large branch of it put into the ground in the rainy season will be capable of supporting the vine in the course of a year; mango-trees may then be raised meantime, as 6–15 years' bearing of the vines suffices to kill the *Erythrinas*. In commencing a plantation upon *Erythrinas*, the ground is usually fenced with a mud wall, and made into terraces. Between mid-July and mid-November, the ground is deeply hoed, and set out with plantains at about 12 paces apart; between the first week in February and first in March, branches of *Erythrina* 6–12 ft. long are planted at 60 paces apart, and watered till the rainy season sets in. Between 10 May and 10 June, the pepper-vines are planted, which may be done in several ways. One plan is to put ½ doz. cuttings each 18 in. long into a basket, which is filled with earth, and buried at the foot of the tree, with the cuttings sloping towards it. Between mid-October and mid-November, the ground around the basket is dug, and the vines are manured with cow-dung and dead leaves. The baskets are said to be a great protection to the plants in their early life, but are often omitted. In either case, during the dry seasons of three years after planting, the vines need watering, in favourable soils, once in 3 days; in dry soils, on alternate days. Between mid-October and mid-November they are manured, and are trained up to the tree till 6 ft. high, after which they are self-supporting. After the 3rd year, the plantains are dug up; and then this manuring and hoeing of the ground is performed twice annually, viz. between mid-October and mid-November, and between mid-July and mid-August. The vines produce in 4–5 years, and are in full bearing in the 6th or 7th, continuing to yield for 12–14 years, when the *Erythrinas* die. In some cases, the trees supporting the vines are pruned, and their branches are lopped; in others, the leaves only are thinned. Mango-trees should be at least 20 years old before having to support the vines.

The Sumatran mode of cultivation differs considerably. The ground is cleared, ploughed, and sown with rice; cuttings of the vine are then planted 5 ft. apart each way, with a sapling of some tree of quick growth and rough bark, in September. The vines are left alone for 12–18 months, then entirely buried, except a small surface of the bent stem, whence spring new shoots, 3–4 of which are allowed to climb the tree planted with them, and are expected to give flowers and fruits a year later. There are two crops annually, the 1st in December–January, the 2nd in July–August; the latter is much inferior in both quantity and quality.

The yield of the plantations varies somewhat according to circumstances. In Sumatra, the dual crop is estimated to average 1½ lb. from each vine per annum. In Malabar, each vine gives a mean of 2 lb. a year up to the 15th–20th year, or about 24 lb. for each tree, which may support 8–12 vines. Sometimes 8–10 lb. is got from a single vine. An acre is reckoned to bear 2500 plants, and to cost not more than 4*l.* to bring into bearing, while yielding a produce worth about 80*l.* when in full bearing. The fruits grow in masses of 20–30 on a single stem. The harvest takes place when they are full-grown and hard, but before they mature, in which latter state they lose pungency and fall off. The season for gathering falls between mid-December and mid-February. The bunches (*amenta*) are hand-plucked in bags or baskets, and the berries (pepper) are then detached from the stem by rubbing with the hands or feet on a mat. The sound berries are then sun-dried for 2–3 days, in a single layer, either on mats or on a patch of smooth ground, being collected in earthen jars at night away from the dew. Mat-drying is said to give a heavier return than ground-drying. The dry pepper is put up in mat bags of 64–128 lb., and is ready for the market.

Our imports of black pepper in 1880 were 21,179,059 lb., 385,108*l.*, from the Straits, and 550,909 lb., 12,979*l.*, from other countries; total, 21,729,968 lb., 398,087*l.* The total in 1879 was only 17,532,958 lb.; in 1877 it was 28,643,635 lb. Our re-exports in 1880 were 12,925,886 lb., 235,801*l.*, chiefly to Germany, Russia, Italy, Holland, and Spain. The fluctuations in our imports from different countries have been as follows:—Java: 2792 lb. in 1876, 74,250 in 1879, none between; Abyssinia: 180,887 lb. in 1876, 0 in 1879, 12,950 in 1880; Siam: 60,000 lb. in 1876, none since; Cochin China: 210,000 lb. in 1876, 0 in 1878 and 1879, 4850 in 1880; Cape: 19,988 lb. in 1876, 180,154 in 1879, 18,642 in 1880; Straits: 27,825,576 lb. in 1877, 16,932,073 in 1879. In the E. Archipelago, pepper-culture is widely spread. It is again assuming large proportions in Atjeh [Atchin or Acheen], the produce being shipped chiefly to Penang and Batavia, Edi on the N.-E. coast (of Sumatra) being the principal mart. In 1822, the Kingdom of Deli had a harvest of 26,000 *piculs*. The country and the people are remarkably adapted to pepper-growing, and the Bataks of N. Sumatra have long been exclusively devoted to it. The value of the foreign exports from Brunei (Borneo) in 1879 was only 362 dol. In 1801, the S. Bornean district of Banjarmassing was alone capable of producing 1500 tons of the spice. The Java exports of the 1878 crop were:—18,832 *piculs* (of 135½ lb.) to Holland, 2773 to Singapore, 1855 to Italy, 1711 to America, 1000 to the Channel for orders, 244 to Australia, 100 to France, total, 26,515; for the 1879 crop, 6106 *piculs* to Singapore, 4571 to France, 3956 to Holland, 1501 to England, 1253 to America, 644 to Italy, 100 to Australia, total, 18,131. Saigon (French Cochin China) had 2177 acres under pepper in 1879, when 4145 *piculs* (of 133⅓ lb.) were sold at the rate of 3*d.* a lb.; in 1878, the exports were 3500 *piculs*, 5000*l.*; in 1880, there was a great falling off, only 3000 *piculs* being brought into the market. The cultivation is extending in Ceylon. China imports large quantities of both black and white pepper.

Of the former, Hankow took 24,805 *piculs* (of 133⅓ lb.), value 49,920*l.*, in 1879; Kiukiang, 5143; Newchwang, 1435; Ningpo, 1257; Shanghai, 2737.

Whole black pepper is seldom or never adulterated in Europe; but in India, the berries of *Embelia* [*Samara*] *Ribes*, are often mixed with the spice for sale in the bazaars. Ground pepper, on the other hand, is frequently sophisticated with starches and other matters detectable with the microscope, despite the very heavy penalty (100*l.*) which has been in force since 1819. The approximate London market values of black pepper are:—Malabar, 3½–5½*d.* a lb.; Aleppy and Tellicherry, 3½–5½*d.*; Penang, 2⅞–4⅜*d.*; Singapore, 3⅛–4¾*d.*

2. *White Pepper.*—This is produced by the same plant as the black pepper, and is prepared by allowing the berries to ripen, keeping them for 3 days in the house after gathering, washing and bruising them in a basket with the hand till the stalks and pulp are removed, and then drying the white seeds. It is said that the lives of the vines are endangered by allowing the fruit to ripen on them. Sometimes white pepper is prepared from black by removing the dark outer layer of pericarp. The article is most largely prepared in the Straits, but the finest is produced in Tellicherry. China is the great market for it. Singapore exported 48,460 *piculs* (of 135½ lb.) in 1877. In 1879, Hankow imported 250 *piculs*, 885*l.*; Ningpo, 238 *piculs*; Shanghai, 357 *piculs*. The London market value of white pepper is about 4⅜–7*d.* a lb.

3. *Long Pepper.*—This is the fruit-spike of *Piper longum* [*Chavica Roxburghii*] and of *P.* [*C.*] *officinarum*, collected and dried shortly before it reaches maturity. The latter is a native of the Indian Archipelago (Java, Sumatra, Celebes, and Timor). The former is indigenous to Malabar, Ceylon, E. Bengal, Timor, and the Philippines, and is cultivated along the E. and W. coasts of India. In Bengal, the plants are raised from suckers set 5 ft. apart in rich, high, dry soil. The yield from an acre is 3 *maunds* (of 80 lb.) in the 1st year, 12 in the 2nd, 18 in the 3rd; after this, the return diminishes, and the roots are grubbed up, dried, and sold as *pipli-múl.* The pepper is harvested in January, and thoroughly sun-dried. It is brought from Java and Rhio to Singapore and Penang for re-export. Singapore shipped 3366 cwt. in 1871, 447 being to the United Kingdom. Penang despatches 2000–3000 *piculs* (of 135½ lb.) yearly. The London market value is 37–45*s.* a cwt.

4. *Ashantee or W. African Pepper.*—This spice, sometimes called also "African cubebs," is the fruit of *Piper* [*Cubeba*] *Clusii*, widely distributed in Tropical Africa, most abundantly in the Niam-niam country, about 4° to 5° N. lat. and 28° to 29° E. long. It is locally used as a substitute for common black pepper, and could be procured in large quantity.

The essential oils of pepper and other species of *Piper* are described on pp. 1420, 1424, 1425.

Pimento, Allspice, or Jamaica Pepper (Fr., *Piment des Anglais*, *Toute-épice*, *Poivre de la Jamaique*; Ger., *Nelkenpfeffer*, *Nelkenköpfe*, *Neugewürz*).—These names are applied to the immature fruits of *Pimenta officinalis* [*Myrtus*, *Eugenia Pimenta*], an evergreen tree of 30 ft., found in some of the W. Indies. The so-called "walks" of these trees, which afford the whole of the spice found in commerce, occupy the limestone hills on the north side of Jamaica. The range of the tree is curiously limited, nearly all attempts to grow it where it is not found spontaneously fail completely. The only way of forming a new walk is to cut down the other growth found upon land where pimento-trees are growing naturally, thus giving scope for their multiplication. The harvest or "breaking" takes place in July–August, the branches bearing clusters of the fruit being broken off by hand, and the berries subsequently sun-dried, stalked, fanned, and bagged for export. The breaking of the branches serves as a rude kind of pruning. The yield of some trees reaches 150 lb. raw, or 1 cwt. dry. There are curious fluctuations in the returns of the acreages under pimento: thus, 7178 acres in 1871, 1392 in 1874, 2363 in 1875–6, 969 in 1877–8 exclusive of trees growing wild on the pasture-lands. The highest export reached was 6,857,830 lb., 28,574*l.*, in 1870–1; in 1877–8, it was 6,195,109 lb. About ⅔ come to England, and ⅓ goes to the United States. The London market value is about 4½–6*d.* a lb. for middling to good, and 4½–5½*d.* for ordinary.

The volatile oil is described on p. 1416.

Soy.—This useful condiment, said to form the basis of almost all the popular sauces made in Europe, is prepared by the Chinese and Japanese from the fruit of *Glycine Soja* [*Soja hispida*], which holds an important place among oil-yielding plants, and has been described under the article on Vegetable Fatty Oils (p. 1378). The condiment is prepared by boiling the beans with an equal quantity of roughly-ground barley or wheat, and leaving it covered for 24 hours to ferment; salt is then added in quantity equal to the other ingredients, water is poured over, and the whole is stirred at least once daily for two months, when the liquid is poured and squeezed off, filtered, and preserved in wooden vessels, becoming brighter and clearer by long keeping. Its approximate value in the London market is 2*s.* 3*d.*–3*s.* a gal. for Chinese, and 2*s.* 4*d.*–2*s.* 5*d.* for Japanese. It is not specified in the trade returns, but doubtless forms the chief item in the unenumerated spices imported from China.

Vanilla (Fr., *Vanille*; Ger., *Vanille*).—This name is applied to the pods of one or more species of *Vanilla*, the bulk of the commercial article being probably derived from *V. planifolia* [*sativa*, *Myrobroma fragrans*], a native of Mexico, now largely cultivated in many tropical countries, as will be presently described. Other species said to afford the spice are:—*V. sylvestris*, in Mexico, perhaps identical with *V. planifolia*; *V. Pompona*, in Mexico; *V. guianensis*, in British and Dutch Guiana; *V. palmarum*, in Bahia; *V. aromatica*, in Brazil and Peru.

The culture and preparation of vanilla are subject to some variation in different localities. In Mexico, plantations are established in virgin forests or open fields. In the former, all shrubs, climbers, and trees causing an excess of shade are cut down, leaving only young trees to serve as supports for the climbing stems of the vanilla plant. Preference is given to those containing a milky sap, as the plant attaches itself to the bark by means of aërial roots, produced from the nodes, and constituting its true organs of nutrition, for the subterranean roots are quite insignificant, and often suffer gradual decay. Close to each supporting tree, two vanilla cuttings are planted side by side in the following manner; the cutting is embedded in a trench 1½ in. deep and 15–20 in. long, as far as 3 joints or eyes, the 3 leaves having been first stripped off, and then covered with dead leaves, humus, coarse sand, brush-wood, &c., the bed being slightly raised above the surrounding level, to prevent stagnation of water around the plant. The remainder of the cutting, 3–4 ft. long, is tied up to the tree. The trees should be 12–15 ft. apart, to allow room for the rapid growth of the plants. After 1 month, the cuttings will have taken root, and need to be carefully freed from weeds and underwood; in the 3rd year, they bear fruit. When planting a field or open level ground, the land is first ploughed up and sown with maize. Meantime a number of young lactescent trees of the fig tribe spring up all over the field, and, in 12–18 months, are capable of supporting the vanilla-plants, which are then set out as already described. The finest product is obtained in this way.

In Réunion (Bourbon), where artificial fecundation is practised, the plants are not allowed to grow out of reach. When starting a plantation in a forest, the cuttings are set at the feet of the trees, whose trunks are connected transversely by a rude trellis; the trees are never lopped, as vanilla requires humidity, and protection from the direct rays of the sun. In making a plantation in an open field, the first care is to grow supports for the plants. Mangoes and fig-trees are employed for this purpose, though preference is given to *Curcas purgans* [*Jatropha Curcas*], the physic-nut, which strikes readily from cuttings, is of rapid growth, and furnishes abundance of milky juice as sustenance for the vanilla-plant; but Holmes has indicated the possible danger of the acrid matter contained in the juice of this tree (see Nuts, p. 1359; Oils, p. 1410) being absorbed by the vanilla-plant. When the young supporting trees have attained sufficient growth to shade the vanilla, cuttings of the latter are planted as follows:—A trench 8 in. deep is dug between the trees and along the lines in which they grow; the cuttings are set in it, and covered with a little humus, dead leaves, and straw. The rainy season is selected for the operation. When the young shoots begin to grow, it is only necessary to guide them along the trellises, and allow the aërial roots to rejoin the trench between the supporting trees; in 2 years, the plantation is in full bearing.

In India, where the cultivation would doubtless be attended with great success and profit, all trees are good protectors except those which change their bark; the best are the mango (*Mangifera indica*), jack (*Artocarpus integrifolia*), ouatier (*Bombax malabaricum*), and physic-nut (*Curcas purgans* [*Jatropha Curcas*]). The last must not be planted alone, as it sheds its leaves when the vanilla is in full bearing. Perhaps none is better than *Erythrina indica*, already widely utilized as a shade-tree in Eastern agriculture. The best planting-season is March–May. The most suitable tiers are the leaves of the vacoua (*Pandanus utilis*), which will have rotted and fallen off by the time that the plants are able to dispense with them.

Spontaneous fecundation of the plant is comparatively rare, as the labellum or upper lip of the stigmatic orifice completely covers the female organ, and the anther rests on that valve of the stigma. In countries where the plant is left to itself, a length of 12–26 in. of vine only produces one pod, though the number of flowers in that length may be 40. All may be artificially fecundated by slipping away the labellum from beneath the anther, and so bringing that organ into direct contact with the stigma; but only the finest flowers (about ½ doz.) on each bunch should be fecundated, or the plant would die of exhaustion. Fecundation is known to be assured when the flower is persistent and dries at the end of the fruit. The remaining buds should be cut off.

As already observed, the fecundated flower decays at the extremity of the ovary, and, after some days, falls off, leaving the persistent gynostem attached to the fruit, which continues to grow for a month, but must be left on the stem for 6 months longer to allow it to ripen. Each pod should then be cut off separately, as it matures, instead of detaching the entire bunch, as is done in some countries. The only certain indication of maturity is the crackling produced when the pod is pinched between the fingers; the apple-green or greenish-yellow colour is not a sufficiently reliable sign. It is quite as important to avoid gathering the pods too soon as too late. If unripe, the product will lack fragrance, colour, &c.; if over-ripe, the pod will be yellow at the end, and, if not already split, is apt to become so in curing.

The odour of vanilla does not pre-exist in the ripe fruit, but is developed by fermentation. When a pod is allowed to remain on the plant, it splits into two unequal parts, becoming first yellow, then brown, and finally black. While it is drying, it exudes an unctuous liquid of dark-red colour called "balsam of vanilla," and, when quite dry, becomes brittle and devoid of all perfume. The following are the various processes for curing vanilla. In Guiana, the beans are placed in ashes, and there left until they begin to shrivel; they are then wiped, rubbed over with olive-oil, and, their lower end having been tied, are hung in the open air to dry. In Peru, they are dipped into boiling water, tied at the end, and hung in the open air for 20 days to dry; they are then lightly smeared over with castor-oil, and a few days later are tied up in bundles. In Mexico, as soon as gathered, the beans are placed in heaps under a shed, protected from sun and rain, and, in a few days, when they begin to shrivel, are submitted to the "sweating" process. This is carried on in two different ways, according to the state of the weather. If it happens to be warm and fine, the beans are spread out in the early morning on a woollen blanket, and exposed to the direct rays of the sun. At about noon or 1 P.M., the blanket is folded around the beans, and the bundle is left in the sun for the remainder of the day. In the evening, all the vanilla is enclosed in air-tight boxes, so that it may sweat the whole night. The next day, the beans are again exposed to the direct action of the sun. They then acquire a dark coffee-colour, the tint being deeper in proportion to the success of the sweating operation. Should the weather be cloudy, the vanilla is made into bundles, and a number of these are packed together into a small bale, which is first wrapped in a woollen cloth, then in a coating of banana leaves, and the whole, enclosed in a mat, is firmly bound, and sprinkled with water. The bales containing the largest beans are now placed in an oven heated to 60° (140° F.). When the temperature of the oven has fallen to 45° (113° F.), the smaller beans are introduced, and the oven is closed tightly. In 24 hours, the smaller beans are taken out; and 12 hours later the larger ones. During this process, the vanilla has "sweated," and acquired a fine chestnut colour. The delicate operation of drying has now to be commenced. The beans are spread on matting, and exposed to the sun every day for about two months. When the drying is nearly complete, sun-heat is no longer needed, and they are spread out in a dry place until the necessary degree of desiccation is arrived at; they are then tied up in small packets. In the Réunion process, the beans are sorted according to length, to be scalded. The long ones are steeped in water heated to 90° (194° F.) during 10 seconds, the medium size during 15 seconds, and the short ones fully a minute. They are then exposed to the sun between two woollen blankets until they acquire the characteristic chestnut colour. After this exposure, which may last 6-8 days, the beans are spread out under sheds to dry gradually. The sheds in this colony being roofed with zinc, they really constitute drying-stoves, through which a current of hot air continually circulates. This desiccation takes about a month, during which time the only care necessary is to turn the beans frequently, so that they dry evenly. At the moment when it is found that the beans may be twisted easily round the finger without cracking—that is to say, when they have acquired a degree of dryness which can be known only by experience—the operation requiring the most minute and vigilant care commences: this is termed the "smoothing" process. The operator must pass every bean between his fingers, and repeat this frequently, for, on drying, the beans exude from their entire surface a natural fatty oil. It is to this oil, which exudes as the fermentation proceeds, that the lustre and suppleness of the bean is due. When sufficiently dry, they are tied up in bundles of uniform length. In this manner, the three commercial sorts are obtained:—(1) "Fine": 8-11 in. long, nearly black, unctuous, glossy and clean looking; these soon become covered with frost-like crystals. (2) "Woody": 6-8 in. long, lighter in colour, more or less spotted with grey, not glossy; these are the pods gathered in an unripe condition; they crystallize very little, if at all. (3) "Vanillons," of which there are two sorts, those obtained from short but ripe fruit, which are excellent, and frost well; and those from abortive and unripe fruit, whose perfume is simply the result of absorption from the fine beans with which they have so long been in contact.

The main centres of vanilla-production are as follows:—Mexico: the slopes of the Cordillera, N.-W. of Vera Cruz, concentrated about Jicaltepec, near Nautla; the *baynillales* on the W. declivity, in Oaxaca State; the States of Tabasco, Chiapas, and Yucatan. E. Mexico exported about 20,000 *kilo.* (of 2·2 lb.) in 1864, viâ Vera Cruz and Tampico, mostly to Bordeaux; the French importations had declined to 6896 *kilo.* in 1871, and 1938 in 1872. Réunion (Bourbon): exported 3 *kilo.* in 1849, and 30,973 *kilo.* in 1877; the crop of 1878-9 was 31,615 *kilo.* The plantations are much injured by periodical cyclones, and by microscopic fungi (chiefly *Bacterium putredinis*), but careful pruning and manuring (phosphoric acid and potash principally, also lime and magnesia) have done much to counteract these evils. Mauritius: this island shipped 7139 lb. in 1872, and 20,481 lb. in 1877; the value was 299,510 *rupees* (of 2*s.*) in 1874, but only 169,966 in 1878. Among other countries, it may be mentioned that the culture is much extending in the Seychelles, and in Ceylon; while the plant is abundant (wild) in Honduras, and grows successfully in Madagascar. Also Panama exported 649*l.* worth to the United States in 1879; and Guatemala, 49 *quintals* to California in the same year. Tahiti exported 1719 lb., 575*l.*, in 1878, and 1426 lb., 570*l.*, in 1879. Very large quantities are grown in Java. The approximate London market values of "salt" pods are 15-40*s.* a lb. for good to fine, and 8*s.*-37*s.* 6*d.* for inferior.

Unenumerated.—Our imports of unenumerated spices in 1880 were from :—China, 7,180,961 lb., 143,476*l.*; British W. Indies, 5,106,803 lb., 104,494*l.*; British E. Indies, 1,781,451 lb., 128,440*l.*; British S. Africa, 1,757,652 lb., 107,504*l.*; Aden, 1,099,733 lb., 68,568*l.*; Native States E. Africa, 723,320 lb., 43,061*l.*; Holland, 414,095 lb., 38,414*l.*; Germany, 213,686 lb., 3542*l.*; other countries, 379,925 lb., 16,806*l.*; total, 18,657,626 lb., 654,305*l.* The total in 1876 was only 7,553,328 lb. The re-exports in 1880 were 12,687,818 lb., 408,623*l.*, chiefly to Germany, the United States, Holland, and Russia. Our imports of unenumerated sauces and condiments in 1880 were from :—China, 893,425 lb., 12,198*l.*; British E. Indies, 314,000 lb., 10,478*l.*; France, 165,040 lb., 4309*l.*; other countries, 112,665 lb., 5169*l.*; total, 1,485,130 lb., 32,154*l.*

Bibliography.—A. Delteil, 'Étude sur la Vanille' (Paris: 1874); J. E. O'Connor, 'Vanilla: its Cultivation in India' (Calcutta: 1875); A. H. Hassall, 'Food' (London: 1876); P. L. Simmonds, 'Tropical Agriculture' (London: 1877); F. Haberlandt, 'Die Sojabohne' (Vienna: 1878); Fluckiger and Hanbury, 'Pharmacographia' (London: 1879); E. von Blaskovics, 'Die Sojabohne' (Vienna: 1880); E. M. Holmes, 'Star-Anise' (Pharm. Jour., Vol. XI. [XL.], No. 547 (London: 1880).

SPONGE (Fr. *Éponge*; Ger., *Schwamm*).

The term "sponge" is commercially applied to the elastic horny skeletons of certain marine animals belonging to the class *Poriferæ*, order *Keratosa*, sub-order *Spongniæ*, family *Spongiadæ*. The commercial grades of sponge in Europe and America coincide very closely. The 3 principal European species are the bath-sponge (*Spongia officinalis*), the horse-sponge (*S. equina*), and the zimocca (*S. agaricina*); in America, these are represented by the glove-sponge (*S. officinalis*, sub-sp. *tubulifera*); the wool-sponge (*S. equina*, sub-sp. *gossypina*), and the yellow and hard-head (both *S. agaricina*, sub-sp. *corlosia*). The most exhaustive account of everything bearing upon the growth and physiology of sponges is contained in Hyatt's very able paper published by the Boston Natural History Society, as quoted in the Bibliography (p. 1821). From it, much of the following information has been derived.

The whole group of *Keratosa* is confined to seas in which the differences between the winter and summer isotherms are not excessive. No American members are found N. of Cape Hatteras and Bermuda; and doubtless a similar limit occurs S. of the equator. On the Pacific shore, S. California and Chili are the extreme points so far known. On the opposite coast of the Atlantic, they are recorded from England to the Cape of Good Hope, and also at the island of Teneriffe. In the Indian Ocean, they are found all along the E. coast of Africa, at the Mauritius, and on the shores of India. They have been described from the S. part of the Sea of Okhotz, on the Asiatic continent, and specimens are not uncommon on the coasts of Australia and New Zealand. In the Pacific, they have been found at the Kingmills Islands and Hawaiian Islands. The extreme outlying form to the north, on both sides of the Atlantic, is the excessively coarse *Dysidea fragilis*, with its fibres loaded with débris. Those from the Cape of Good Hope and S. Australia also belong to the coarser genera. It would seem, therefore, that the finer skeletons of the *Keratosa*, those of the genus *Spongia*, are only to be sought in the intermediate zone, where the waters are of equable and high temperature. And in examining the species of this genus with relation to each other, it becomes equally evident that they are finest and most numerous in archipelagoes, or off coasts which are bordered by large numbers of islands or long reefs, or in sheltered seas. The sponges near Nassau (Bahamas) lie on reefs very much exposed to the action of the waves, often 30 miles from land, and always in currents, sometimes running 3–4 knots an hour. Such currents are usual where groups of islands confine the tide-water within certain definite channels, and they have also the effect of concentrating the floating food in the channels, or wherever tides meet. Both these conditions are essential to successful sponge growth, viz. a continuous renewal of aërated water, and a plentiful supply of food, and are probably partly the cause of the abundance of sponges in such places. Constant reference to physical influence is also noticeable in the method of classification adopted by Von Eckhel.

The marketable qualities of sponge are described as "sorts," and the different sorts are designated by letters, as "sort A." These sorts are most conveniently arranged according to localities, and thus under some sorts all three species are represented; all, however, are from the same place, and all have some local peculiarity which makes them either of superior or inferior quality. The slimy character of the bottom is often given as a reason for inferiority or dark colour. On the American side of the Atlantic, this is also shown by the great difference in point of colour and fineness between the Nassau and Key West sponges. Again, the shallow-water sponges are coarser than the deep-water forms. This is probably due, in part, as in other species, to the quantity of sediment, which is of course less in deep than in shallow water, as, for example, at Key West in the winter time. No fine qualities of any sponges are found within the limits of the milky water, but all the finer qualities of the marketable kinds in the deepest water in which the species occur, except, perhaps, in the case of the reef sponge. Glove, reef, and hard-head are fished in shallow waters (greatest depth 2 fathoms), and the other and generally finer marketable varieties at 2–5 fathoms. This fact also explains in a measure, but not wholly, the greater coarseness of American sponges as compared with the European; for though it may be assumed from the examination of the skeletons that Mediterranean sponges are much less exposed to turbid waters, and though it may be shown by the microscope that the primary fibres contain less débris, this does not wholly explain their greater fineness and elasticity. This may be attributed either wholly or partly to climatic conditions. Both the bathymetrical and geographical distributions of the *Spongiæ* seem to be limited by the minimum temperature of 13° (55° F.). The N. shore of the Ægean Sea and the E. shore of the Adriatic are populous with sponges, and yet the former throughout its whole extent, and the latter from Ragusa to Istria, have nearly the same average winter temperature as, and possess a colder climate in winter than, the coast of S. Italy or Spain, where no *Spongiæ* exist. The sponges correspond in quality to this climatic change. The sort found at the head of the Ægean is said to be *S. officinalis* alone, and to have a heavy, hard, close, very hairy skeleton, often containing slime. The same species exists also alone at corresponding localities along the shore of the Adriatic, and at the extreme locality, the island of Istria, upon the limit of its distribution, it is said to be very rare, the form to be ugly, the skeleton hard, the colour dark. Farther south, along the Dalmatian coast, it becomes abundant, finer in texture and of a lighter colour, but it is still inferior to the more southern or Levantine variety. In considering such classes of facts, it must also be borne in mind that the habitat of a certain sort or variety may largely determine the quality of the skeleton, even where the temperature may be very favourable. Thus, to the south of Quarnero, among the islands, a much better quality of *S. officinalis* occurs than in the milder sea about the Ionian Islands, which is probably attributable to the slimy character of the bottom. It would seem, from the absence of sponges where they might be expected to occur, that when the limits of temperature are neared, the lack of small islands, or very slight local peculiarities, may suffice to account for commercial sorts (to which our knowledge is confined) being wanting.

The finest sponges in the Mediterranean, those of the Levant and off the Syrian and Tripoli coasts, are found between the average aërial temperatures of 17° and 21° (63°–70° F.), and the isochrymals of 10°–14° (50°–57° F.), and probably at no time of the year are these, which occur in the deeper water at a distance from the coast, exposed to a lower temperature than 15½° (60° F.). In America, the whole region favourable to the production of the commercial qualities lies between St. Marks, on the coast of Florida, with an isotherm for January of 17½° (63½° F.), and the equatorial isotherm for January of 27° (80° F.); south of this equatorial isotherm, however, the limits have not been ascertained, the data, both as regards the sponges and the temperatures, being deficient. The finer sorts are only found along the W. coast of Florida, among the Keys, and in the insular waters of the Bahama and Caribbean Islands. Their absence from a large part of the shore of the Gulf of Mexico may be attributed to the sandy or soft character of the coast, the silt of the Mississippi, and the absence of outlying islands; the open and sandy or clayey character of the Atlantic coast northward to New York explains their non-occurrence there.

The sponges of the Red Sea are inferior to and rarer than those of the Mediterranean; they most resemble the zimocca kind, the skeleton being brittle, entirely red, and very dark at the base; and the two sorts are sold mixed. It therefore seems that the high temperature of the Red Sea, in presence of perfectly clear water, is not so detrimental as where the waters are more loaded with sediment, as in the shallows of the Florida coast, or the specimens could not be sold commercially in the company of even the inferior Mediterranean qualities. The few true Australian *Spongiæ* are coarse, and have an excessively dark rough skeleton. The Sydney sponges, found under the marine isochrymal of 62° F., on an open and unfavourable coast, are presumably beach specimens, drifted from the coast of Queensland, which, inside the great boundary reef, is probably exceedingly favourable to the growth of the true *Spongiæ*. From all the ascertained facts, Hyatt deduces five rules as governing the quality of commercial sponges:—(1) The inferiority of the skeleton, which is common at Key West, with the same isochrymal as the Red Sea, is not found in the same degree in the sponges growing in the clearer waters of the latter; (2) the coarsest qualities of all the Mediterranean sponges, the "Gerbis" and others, grow in localities along the coast, where they are most subject to the action of suspended matter in the water; (3) but all of these are, on account of the clearness and medium temperature of the Mediterranean waters, as compared with those of other seas, of much finer quality; (4) the coarser kinds of the same quality or variety grow nearest the shore, and the finer kinds in deeper water, and, according to Nassau (Bahamas) spongers, are more apt to occur upon marly ground, where the sediment is finer than upon other kinds of bottom; (5) the inverse ratio between the quantity, and even the prevalence, of different kinds of sediment, such as sand grains or spicules, and the resiliency and flexibility of the fibres of the sponge, may be demonstrated with the microscope in any series of specimens.

The openness or apertion which usually accompanies and appears to correlate with the coarseness of fibre cannot be accounted for in this complicated way, but must be considered as an element of inferiority always accompanying a skeleton having loose microscopical texture or mesh, and harsh, inelastic, easily torn fibres; but it is also, though rarely, found in specimens of very fine quality, especially at an early age. It is a common characteristic of all inferior qualities of Mediterranean, and of all Caribbean commercial sponges without exception; the latter, whether with very fine or very coarse and inelastic fibres, are always permeated in the interior, and have the surface also cut up, by larger and more numerous canals than the corresponding Mediterranean species. The Australian *Spongia spp.*, though coarser in fibre than the Caribbean, are equally open, and usually much harder when dry. The evidence afforded by unmarketable varieties found in very hot climates, and all of which have very open, coarse, and brittle skeletons, confirms the opinion that this characteristic of apertion may with good reason be attributed perhaps exclusively to the influence of unfavourable temperature, which may be either a degree of cold indicated by an isotherm of about 50° F. for the coldest months, or the equally injurious heat shown by an average for the same months of 65°–80° F.

With regard to colour, a darkening of the fibres about the base, and frequently of the whole sponge, may occur with any of the inferior qualities in any cold climate or unfavourable situation, as at Istria, and varies with the age and size of the specimen. These influences, however, never produce so marked an effect as in a hotter climate, nor does the deterioration of the fibre and of the density of the skeleton go so far; nevertheless, the Nassau sponges, which are lighter coloured than the Gerbis, and the foregoing remarks upon the influence of suspended matter near the shore, point to the fact that heat does not entirely control the colour, though it may largely influence it. Another point in this connection is that the deepest colour is always in the interior, and the lightest coloured parts are external, in the position most exposed to the action of light; and this, though not necessarily, is probably the hottest part of the organism during the heated term of the year in the shallower waters, where the darkest-coloured forms are mostly found. It has been suggested that this coloration was due to iron in the sediment or sea-bottom; but this could hardly be the case in the vicinity of coral reefs, and the dark internal coloration appears to result from or correlate with the deterioration of the skeleton as an internal change in structure, varying with the species, the age, and the health of the specimen, and probably with the chemical composition of the fibres themselves.

The distribution of the species is quite remarkable. Only one species (*Spongia officinalis* [*adriatica*]) is found on the E. shore of the Adriatic and coast of Greece, from Trieste to the Bay of Nauplia. From Nauplia and the island of Candia to Eritra, on the coast of Asia Minor, two occur, *S. officinalis* and *S. agaricana* [*Zimocca*]. From Eritra, opposite the island of Chios, to Tripoli, all three, *S. officinalis*, *S. agaricana*, and *S. equina*, are fished, except at the island of Cyprus, where the zimocca sponge does not live. From Tripoli to Tunis, two only occur, *S. officinalis* and *S. equina*; and from thence to Ceuta, at the Straits of Gibraltar, a very peculiar dark-coloured and coarse variety of *S. equina* is obtained, called the Gerbis (Gerba) sponge. The dealers have thus to do with a vast variety of forms. They can, however, pick out the three species and their varieties without hesitation, being led mainly by the general aspect of the surface. This has a distinct appearance in every species, and, though much altered by the greater or less development of superficial tufts, is much more constant than any other character. This is due to the fact that the surface takes its aspect largely from the number, distribution, and size of the pores, cloacal orifices, superficial canals, and primary fibres. These characteristics, of course, are directly correlated with all that is important in the internal anatomy of the animal, and should therefore be more constant than the length, form, or composition of the tufts of fibres, or the shape of the whole, which are capable of great modification, according to the locality in which the specimen may be found. The forms of *S. officinalis* may vary from cup-shape to fistular, and to irregular or lump-like. The latter are usually coarser and looser in texture, the superficial tufts are longer and more numerous, and they approximate more closely to the coarser varieties of sub-sp. *tubulifera* of the Caribbean Sea, in the external aspect of the surface and the apertion of the interior, than the finer varieties. The texture of the poorest variety of the Mediterranean sponges is, however, always better for domestic purposes than the best of the corresponding American varieties, being firmer and more elastic; and it is also to be remarked that the latter never have the cup-shape, which is so common in the sub-sp. *mediterranea*, and that the fistular form takes its place. The forms of *S. agaricina*, sub-sp. *Zimocca*, vary from saucer-shape to irregular lump-like growth. As in *S. officinalis*, it may be shown that these aberrant forms are quite similar to the aberrant or formless varieties of the sub-sp. *punctata* of Florida, as regards the aspect of the surface; but these also are nevertheless much finer than the finest varieties of the latter. Here, again, the platter- or saucer-shape, which is a modification of the cup-shape, is absent. *S. equina* exhibits similar degrees of variation in the texture of the surface and the form. There are no proper cup-shaped specimens among the American varieties of sub-sp. *gossypina*, but, in place of these, the fistular form. These occur generally associated in clumps, more or less densely filled up into heads, and solid; but sometimes the tubes are almost isolated. The younger specimens of this species have a very loose and open texture, due to the approximation and large size of the openings, and, to a less degree, this is also to be remarked in the Gerbis sponge. The former approximate in aspect to the coarser qualities of the American species; so also does the latter, which has very nearly the same colour and aspect as the dark-coloured Key West specimens, but it is not so coarse and dark. It seems, then, that there are three sub-species of commercial value in the Mediterranean, which find their way into the New York and European markets. The coarsest varieties of the European sponges are finer, firmer, and more elastic than the finest of the corresponding American sub-species. This is directly traceable to the larger amount of foreign matter included in the primary threads, and the looser mesh of the tissue; the fibres are also comparatively coarser, and the large cloacal channels more numerous throughout the mass. The shape does not necessarily correlate with a finer or coarser skeleton, but probably with a more or less extended base of attachment, and with local peculiarities, such as currents, the kind of bottom, &c., which have not been investigated in this connection.

Sponges always grow on hard surfaces—rock, coral reef, bricks, the barren stems of sea plants, &c. They are sought for in shallow water by the aid of a water-glass, which is a tube of thin boards or iron pipe several feet long, with a pane of glass at one end (often merely a bucket with a glass bottom), which, when submerged, prevents the sight of the fisherman being disturbed by the glare of the reflecting surface and by its incessant motion. The latter obstacle alone is sometimes overcome by simply pouring oil on the surface of the water. When found, they are dislodged either by divers, or by so-called "harpoons." The divers descend either naked or in special dresses. When naked, they are carried down by a block of stone weighing some 25 lb., held at arm's length in front. The usual depth is 15–20 fathoms; but some divers successfully reach 40 fathoms, after inflating the chest for about 10 minutes. The ordinary duration of a dive is 1–2 minutes, and 3½ is the maximum. The use of the harpoon, a kind of fork on a thin pole 3–6 fathoms long, dispenses with diving; it is used for the coarser Mediterranean and most of the Caribbean sponges, which grow in shallow water, and are not worth the risk and trouble of diving. A third plan is by dredging with a drag-net, which tears up the sponges and collects them in a bag behind.

About 12 hours' exposure to the air suffices to kill the sponge. Subsequent operations are designed to free the skeleton from the animal's remains. In the Mediterranean, as soon as the first sign of putrefaction makes its appearance, the sponges are tied to strings and kneaded in sea-water with sticks or with the feet, till the "milk" or sarcode and the skin are quite removed, the latter being sometimes scraped off with a knife. This is performed much more rapidly in warm than in cold weather. Sponges should always be washed if possible within 24 hours of their capture, never being so good if left till the next day. When perfectly clean, they are dried by exposure to the air, and then packed in bales. If packed before fully dry, they heat and become spoiled, assuming an orange-yellow colour; partial remedies for this have been found in the weak acids, as citric, and in alkaline solutions. Sponges may be bleached by sulphurous acid, or by Blondeau's recipe, which is as follows:—They are first washed in warm water, and then in a solution containing 0·5 per cent. of hydrochloric acid, to remove the carbonate of lime; the actual bleaching is effected by a 24 hours' immersion in a bath containing 5 pints hydrochloric acid, and 6 pints hyposulphite of soda, in 100 pints water. This is said to be a more effectual and rapid process. But all bleaching must be at the expense of the durability of the sponge. In America and the Bahamas, want of care marks the conduct of the operations, the "killed" sponges being cast into pens formed by stakes driven into shallow water, called "crawls," and left to decompose as they may. They are finally squeezed, washed, dried, and sun-bleached. In the S. Pacific, much the same method prevails, the sponges being suspended from a light framework, so that they are washed by the tide when up, and exposed to wind and sun while the tide is out.

The chief localities of sponge-fishing cited by Eckhel are as follows:—The bays of Patras, Corinth, Koron, Marathonisi, Nauplia, Kranidi, Budrum; the islands of Cerigo, Hydra, Spezia, Ægina, Poros, Salamis, Astrupala, Samos, Pathmos, Leros, Nisseros, Kalymnos, Symi, Chalki, Rhodes, Candia, Cyprus; on the W. coast of Asia Minor, the localities of Chesme, Eritra, Samos, Mendelia, Dschovata, Makry; on the Syrian coast, Latakia, Tarabulus, Ruad Island, Batrun, Dschebel, Beyrout, Caiffa, Jaffa; the Straits of the Dardanelles, and the Sea of Marmora. The "harpoon" fishing is carried on chiefly at Nauplia, Kranidi, Hydra, Spezia, Ægina, Poros, and Salamis, while the divers affect Symi, Kalymnos, Chalki, and Castell-rosso. Eckhel further classifies the 3 species into the following commercial sorts:—(A) Dalmatian: (1) Istria, (2) Dalmatia; (B) Patras or Gulf; (C) Greek: (1) Koron, Marathonisi, and Cerigo, (2) Nauplia, Kranidi, Hydra, Spezia, Ægina, Poros, Salamis; (D) Turkish: Volo, Trikeri, Argalesti; (E) Bugaso: Dardanelles and Marmora; (F) Astrupalia; (G) Island: (1) Samos, Pathmos, (2) Leros, Nisseros, (3) Budrum, (4) Kalymnos, (5) Symi, (6) Chalki, (7) Rhodes, (8) Castell-rosso; (H) Kankava: Chesme, Eritra, Samos, Mendelia, Dschovata, Makry; (I) Candia; (K) Karamania; (L) Cyprian; (M) Syrian: (1) Latakia, Ruad, Tripoli, (2) Batrun, Dschebel, Beyrout, Caiffa, Jaffa; (N) Mandrucha or Barbarian: (1) [Katomeri] Arabian Gulf, Gatta Gulf, Mellach, (2) [Panomeri] from Mella to Derna, (3) Bomba, Tobruk, Ras-et-Tin, Tunia; (O) Bengazi; (P) Gerby or Sfax: Tunis; (Q) Red Sea; (R) Bahamas.

The exports of sponge from Syra in 1879 were:—4023*l.* worth to Great Britain (18,689*l.* in 1877), 7242*l.* to France, 1827*l.* to Austria. The average value of the Greek sponge is 2*s.* a lb. Tripoli yearly produces 25,000-35,000; the exports in 1878 were 15,000*l.* worth to England and France. The United States fisheries produced 12,995 lb., value 5044 dol. (of 4*s.* 2*d.*) in 1877; the returns for 1877 and 1878 are incomplete. The exports of sponge from the Bahamas have fluctuated in value as follows:—1869, 24,917*l.*; 1870, 14,104*l.*; 1873, 32,938*l.*; 1877, 17,337*l.*; 1879, 33,265*l.* The qualities and values of the Bahaman sponge exported in 1878 and 1879 were:—

	1878.		1879.	
	lb.	£	lb.	£
Boat	19,165	686	19,817	737
Glove	17,292	521	10,866	369
Grass	174,228	2,003	132,491	2,987
Hardhead	37,530	1,560	36,538	1,704
Mixed	4,320	149	9,082	271
Reef	33,840	2,934	42,334	3,682
Refuse	14,322	210	1,972	24
Velvet	62,708	5,277	101,184	8,843
Wool	86,393	10,406	102,862	13,258
Yellow	35,787	990	41,301	1,410
	485,585	24,736	504,447	33,285

Our imports of sponge from the Mediterranean were 189,828 lb. in 1851; 411,111 lb., 270,410*l.*, in 1860; 453,819 lb., 113,384*l.* in 1870. Our total imports were 1,221,673 lb., 156,965*l.*, in 1869; 837,159 lb., 160,162*l.* in 1870. There are no records since. The approximate London market values of sponge are:—Turkey: fine picked, 16–22*s.* a lb.; fair to good, 7–10*s.*; ordinary, 8*d.*–3*s.* 6*d.*; Bahama, 5–10*d.* The ordinary applications of sponge are sufficiently familiar. Attempts have been made to utilize the very inferior qualities, which are unfit for use as sponge, for the manufacture of a kind of felt. The process consists in softening with glycerine, cutting small, carding, and felting. The manufacture does not appear to have flourished long.

It would be an omission to conclude this article without an allusion to the efforts which have lately been made to artificially improve sponge-culture. The object aimed at was the multiplication of sponges by cuttings; but inasmuch as the cuttings were found to produce no greater return than would have been given in the same time by the single specimen uncut, the only advantage derivable from the process would be the possibility of populating suitable unoccupied ground with cuttings of commercially valuable kinds. Details may be consulted in Dr. Marenzeller's paper quoted in the Bibliography (translated in the Society of Arts Journal, Vol. xxix., No. 1488), and in the Pharmaceutical Journal, Vol. xi. [xl.], No. 547, pp. 491–3.

Bibliography.—O. Schmidt, 'Spongien des Adriatischen Meeres' (Leipzig: 1862, sup. 1864); G. von Eckhel, 'Der Badeschwamm' (Trieste: 1873); A. Hyatt, 'Revision of the N. American Poriferæ' (Memoirs Boston Soc. Nat. Hist., Vol. ii., Part iv., No. ii. [1875], and Vol. ii., Part iv., No. v. [1877]; E. von Marenzeller, 'Aufzucht des Badeschwammes aus Theilstücken' (Verhandl. k. k. zool.-bot. Ges., Vienna: 1879); A. Hyatt, 'Commercial and other Sponges' (Boston: 1879).

STARCH (Fr., *Fécule*, *Amidon*; Ger., *Stärke*).

The term "starch" is applied to the fecula or amylaceous matter contained in the fruits, roots, or cellular tissue of by far the greater number of plants, and extracted from a few on a commercial scale. It occurs in grains of various sizes, having when pure a slightly yellowish colour, and whose form and structure are characteristic for each kind; the bluish tint of laundry-starch is due to the addition of a mixture of smalt and alum in water: such starch is considered unfit for dietetic or medicinal use. The sp. gr. varies with the kind of starch, and with its dryness; the amount of water reaches 30 per cent. in some instances, and at times descends to 7 when air-dry. The formula is variously given as $(C_6H_{10}O_5)^2 + 3OH_2$, $C_{18}H_{30}O_{15}$, and $C_{36}H_{62}O_{31} + 12OH_2$. Some starches are prepared for use as alimentary substances, while others are only converted into an article for industrial application. The best qualities of starch serve for sizing paper, especially fancy papers (see pp. 1489–90). The finest starch is used for the manufacture of white glucose syrups (see Sugar—Starch-sugar), for finishing textiles (see pp. 770–6, 1185), for making white dextrine (see pp. 1645–7), as well as for preparing farinaceous food and fine pastry. Inferior sorts are used for the same purposes when the quality is not of such importance, as for instance, for weavers' dressing, as a means of thickening mordants (see pp. 1293–1305), and colouring substances for cloth printing (see pp. 835–54). By fermentation, it produces glucose and then alcohol (see pp. 192–214). Another important application is the "dusting" of the forms in metal foundries, in lieu of charcoal dust. Its use for stiffening ("starching") linen and washed clothes is well known.

The principal kinds of starch will now be separately described. They can be distinguished under the microscope by the shape of the granules: in rice, they are small and angular; in maize, angular but larger; in wheat, lens-shaped; in potato, arrowroot, and *tous-les-mois*, more or less ovate; in tapioca, muller-shaped. They vary in size from $\frac{1}{250}$ to $\frac{1}{10000}$ in.

Arrowroot.—The name "arrowroot" embraces the amylaceous matter of several kinds of plant very widely disseminated in the tropics. The most important of these is *Maranta arundinacea*, a native of the W. Indies and Tropical America, from Mexico to Brazil, and occurring under the form known as *M. indica*, which has narrower, sharper, and always smooth leaves, in Bengal, Java and the Philippines. It is also cultivated in Mauritius and Natal, and on the W. coast of Africa.

In Bermuda, arrowroot is planted in May and ripens in March–April; it is manufactured in April–May, during the cold winds. The process is simple. The washed rhizomes are reduced to a pulp, which is strained through sieves of progressive fineness, allowed to settle, collected, passed through the finest sieve into clean water, settled, and the layer of brown colour removed from the surface. This brown starch is the more astringent of the two, and is locally preferred. After a final passing through the finest sieve, and settling, it is placed on cloths to harden, broken up fine on trays, and dried in the sun and wind. About 100 lb. good arrowroot may be got from 4 barrels of the peeled and cleaned rhizomes, about 24 hours being the duration of the water process. In Jamaica, rude machinery is used for the pulping operation. The one great precaution necessary is the absolute avoidance of contamination with dust, rust, insects, or anything capable of communicating odour or colour; hence a good supply of pure water (especially free from iron) is pre-eminently requisite. The refuse of the plant forms excellent pig-feeding material. The production and exports of arrowroot from the W. Indian Islands are exhibited in the following figures. Bermuda shipped 10,334*l.* worth in 1851, which gradually decreased till the quantity in 1870 was only 25 cwt. The quality of Bermuda arrowroot has never been surpassed, mainly on account of the care exercised in its preparation. Jamaica has about 50–60 acres under arrowroot; the exports were 70,204 lb. in 1866, 13,193 in 1871–2, 1636 in 1873–4, 21,983 in 1874–5, 3514 in 1876–7. St. Vincent shipped 10,379 bar. in 1870, 17,669 in 1877, and 14,916 in 1879. Barbados exported 114*l.* worth in 1877, and 24*l.* in 1878. Grenada shipped 20 lb. in 1878. In the adjacent colony of British Guiana, the plant is readily cultivated, but the product is very inferior through carelessness in the preparation. Dutch Guiana (Surinam) exported 621½ *kilo.* (of 2·2 lb.) in 1877, and 89 in 1878.

In Natal, arrowroot-culture is carried on chiefly in the counties of Durban, Victoria, and Tugela; also in Cape Colony. The land, preferably old, is well ploughed and broken up at the commencement of the rains; sets taken from old stools are planted thickly in a simple plough-furrow, and covered with earth turned out of a parallel furrow. The plant grown is the same as in the W. Indies, and the mode of preparation is practically identical. The area occupied by arrowroot in Natal was 226 acres in 1864, and 386 in 1870. The yield varies much: 61 acres in Tugela gave 1220 cwt.; 66 in Victoria, 639; 98 in Durban, 488. The exports were 6366 cwt. in 1859, 1206 in 1874.

The same plant is considerably cultivated in India, but much of the E. Indian arrowroot is afforded by another genus. In the S.-W. districts, notably Travancore, Cochin, and Canara, *Curcuma angustifolia*, *C. leucorrhiza*, and perhaps some other species, are extensively grown, and their starch, known as *tikor* or *tikhar*, is prepared by rude processes.

Maranta nobilis seems to be the kind chiefly cultivated in New South Wales. Queensland grows not only *M. arundinacea* and *C. edulis*, but also 3 species of *Manihot* (see Tapioca, p. 1828). The area occupied by arrowroots of all kinds in Australia in 1879 was:—Queensland, 132 acres; New South Wales, 27 acres (produced 47,484 lb.); Victoria, 4 acres (produced 67 cwt.). Queensland in 1869 exported 26,368 lb., value 548*l.*

Several species of *Canna* are cultivated for their starch, that produced in St. Kitts being known as *tous-les-mois* (a corruption of *toulema*, *tolomane* or *touloula*). The species have not been accurately determined, but it would appear that *C. edulis* [*indica*] is the one mainly or exclusively raised in the W. Indies, while others mentioned are *C. Achiras*, a native of Peru, *C. flaccida*, of Carolina, and *C. glauca* and *C. coccinea*. The island of St. Kitts (W. Indies) exported 51,873 lb. of this arrowroot in 1876. Some is also produced in Australia (from *C. edulis*), the plants being set in ordinary ploughed land, and harvested in April. *Tous-les-mois*, when boiled with 20 times its weight of water, yields a more tenacious jelly than the *Maranta*-starch.

Tahiti or South Sea arrowroot is obtained from the tuberous root of the *pia* of Tahiti (*Tacca pinnatifida*), a plant affording over 30 per cent. of starch, also said to occur in China, Cochin China, the Moluccas, Zanzibar, &c. The area occupied by the culture of this plant in Fiji in 1879 was 2215 acres. Other species met with in India, Madagascar, Guinea, and Guiana, might be utilized in a like manner. The starch of *T. involucrata* is extracted on the W. coast of Africa.

Arrowroot is also locally obtained and used from various species of *Zamia* · in Florida, under the name of *boonti*, from *Z. integrifolia* and *Z.* [*Encephalartos*] *spiralis*; in Queensland and W. Australia, from another species, which contains 30 per cent. of starch resembling arrowroot in feel and taste. Portland arrowroot, not now to be met with in commerce, was formerly prepared from the roots of *Arum maculatum*, in the island of Portland. Small quantities of starch are also obtained from *A. italicum* in Italy. The starch of the root of *Alstrœmeria Ligtu* and other species is used as arrowroot in Chili.

Arrowroot is a brilliantly white, insipid, odourless powder, crackling under pressure in the hand, of sp. gr. 1·565 after drying at 100° (212° F.). The various kinds may be distinguished by the microscope by the differences in the size and form of the granules. The chief commercial kinds and their values are:—Bermuda, 1*s.*–1*s.* 6*d.* a lb.; St. Vincent, 2½–7½*d.*; E. India, 1¾–2½*d.*; Natal, 3½–7*d.* The imports of arrowroot into the United Kingdom in 1870 were 21,770 cwt., value 33,063*l.*; the value in 1875 was 56,143*l.*; there are no returns since. The domestic consumption of arrowroot is sufficiently familiar.

Buckwheat-starch.—A few English firms prepare starch from buckwheat (*Polygonum fagopyrum*). It is a fine powder of nearly pure-white colour. (See Wheat-starch, pp. 1828–9.)

Greenheart-starch.—The starch obtained from the seeds of the greenheart or *bibiri* tree of British Guiana (*Nectandra Rodiœi* [*leucantha*], to the extent of 50 per cent. and upwards, is locally used as food in times of scarcity. It has a bitter flavour and pale-brown colour, and is said to possess febrifuge and tonic properties.

Horse-chestnut starch.—The fruit of the horse-chestnut (see Nuts—Chestnut, pp. 1352–3) contains 16–36 per cent. of starch, which is readily extracted by the methods that are adopted for corn-starch. The preparation of the article is largely carried on in S. France, 100 lb. dry starch being obtained on an industrial scale from 240–250 lb. of the "nuts." The bitterness is removed by treating with water containing carbonate of soda.

Maize-starch.—The grain of the maize or Indian corn plant (*Zea Mays*) contains a large proportion of starch, the average quantity being about 53½ per cent. in flat yellow American maize, and 54¾ in the flat white and round yellow varieties. In its occurrence and association, the starch of the maize closely resembles that of wheat; it differs in that the accompanying gluten forms a less tough mass, and may be separated without having recourse to fermentation, thus affording a bye-product of greater value for cattle-feeding purposes. The grain is cleaned, soaked in water for 24–30 hours, crushed in a roller-mill or ground to paste between millstones, and washed in cylinder-sieves as described for potato-starch (see Fig. 1287, p. 1825). The starch-milk thus separated is poured upon inclined tables where the starch granules are deposited, while the nitrogenous matters pass on to capacious tanks, and gradually subside, to be subsequently collected and mixed with the hulls for cattle-food. The starch which settles in the inclined tables forms a good paste for finishing textiles, without further treatment. The quality may be improved by the application of alkaline solutions, which dissolve the remaining gluten.

There are several modified methods of manufacturing maize-starch. Watts steeps the maize at a temperature of 25°–60° (77°–140° F.) until slight fermentation has set in. Leconte soaks the grain in a caustic soda solution, washes it in a wire sieve, and crushes it between millstones on which plays a jet of water. The starch-milk is filtered on to the inclined tables.

The finer qualities of maize-starch are largely used as a substitute for arrowroot and for making biscuits, while the lower grades serve for laundry purposes. The most extensive factories where it is produced are Brown and Polson's in Scotland, Erkenbrecher's in Cincinnati, and the Glen Cove Co. in New York; it is also made in Brazil, New South Wales, France, and Hungary on a considerable scale.

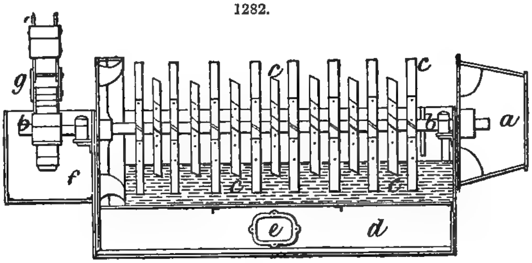
Plantain-starch.—This starch, sometimes called Guiana arrowroot or plantain-meal, is extracted from the unripe fruit-pulp of *Musa paradisaica*, by slicing, sun-drying, powdering, sifting, and washing with water. The article is mostly exported as meal to Europe, and the starch is manufactured after arrival. The flour is said to contain 66 per cent. of starch.

Potato-starch (Fr., *Fécule de Pomme-de-terre*; Ger., *Kartoffelstärke*).—The potato (*Solanum tuberosum* [*esculentum*]) contains starch to the extent of 15–25 per cent.; the amount varies according to the soil, climate, manuring, and storage—freezing and sprouting being alike detrimental. About 66–75 per cent. of the contents are obtained by the manufacturer.

There are chiefly two methods of manufacturing potato-starch. According to the older and commoner plan, the potatoes are first cleaned and then grated. The cleaning embraces the washing away of the attached dirt, and the elimination of stones and other foreign bodies. Many machines have been devised for the purpose, one of the best being Venuleth's, shown in Fig. 1282. It consists essentially of an iron receptacle *a* for the dirty potatoes, a shaft *b* carrying wooden beaters *c*, which revolve in a trough of water, provided with an iron grating which allows the dirty water to escape into a lower trough *d*, whence it can be withdrawn at the door *e*. The washed potatoes pass into the box *f*, ready to be conveyed by the elevators *g*, into the grating-machine, which usually stands on the floor above.

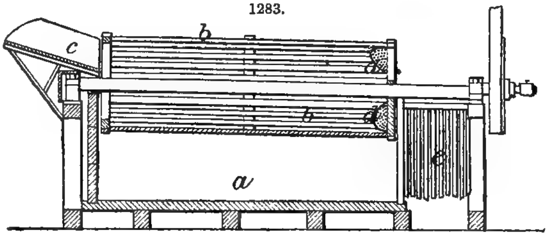
Another form of washing apparatus is shown in Fig. 1283, and is known as Champonnois'. It consists of a wooden tank *a* filled with water, in which revolves a cylinder *b*, formed of open woodwork. The potatoes are fed by the hopper *c*, washed by the rotation of the cylinder, and thrown by the lips *d* upon the external inclined plane *e*, also formed of laths.

1282.



The grating or grinding of the washed potatoes ruptures their cells, and liberates the starch to a greater or less degree. Of the numerous graters in use, one of the best is Champonnois', shown in Fig. 1284. The potatoes are introduced by the hopper *a*, and are forced by the rapid rotation of the fliers *b* (800–1000 rev. a minute) against the short saw-like teeth of the raspers *c*. Water is at the same time injected at *d*; *e f* are the fast and loose pulleys, and a fly-wheel is fixed on the end of the shaft *g*. The motion of the machine is reversed every 6 hours to equalize the wear, still the raspers require sharpening after 48 hours' use. The whole interior needs frequent washing out with clean cold water, and the raspings should be removed at very short intervals.

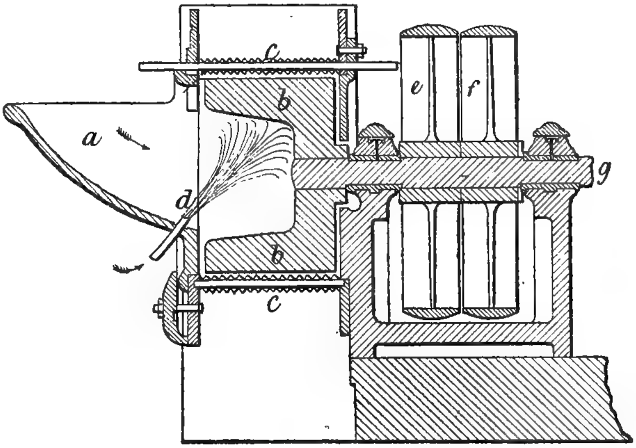
1283.



The grated paste next requires treatment to separate the starch-granules from the cellular and fibrous matters. This is effected by sifting-machines of various kinds with the aid of water. One of the simplest forms is shown in Fig. 1285; the brushes *b* rotate over the surface of the wire or hair sieve, while water is supplied by the pipes *a*; motion is given by the pulley *c* and bevel-wheels *d*.

Siemens' bolting-sieve is shown in Fig. 1286. The grating-cylinder *c* is secured to a simple wooden frame *e*; the paste falls from the cylinder upon the bolting-sieve *h*, supported from the frame by bars *f*. The grating-cylinder is driven by a pulley, and transmits motion to the pulley *d*, which connects with the sieve by the bar *g*. The sifted paste is conducted by *k* to the receptacle *l*. Water is admitted to the cylinder at *a*, and to the sieve at *i*, while *b* is the feed-hopper. The liberated starch is conducted into settling-tanks.

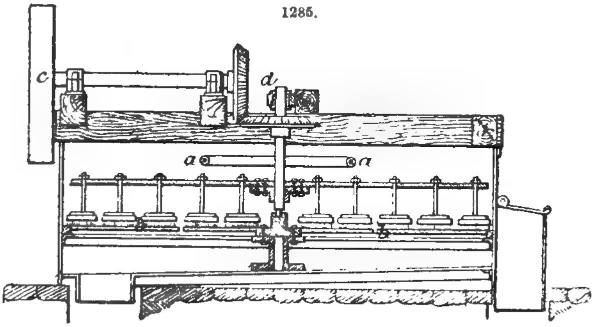
1284.



Huck's sieve, Fig. 1287, is composed of three sieves *a* placed end to end, but separated by cylindrical chambers *b* of greater diameter. The mesh of the sieves is of increasing degrees of fineness. The sieves rotate in the opposite direction to the brushes which impinge upon their surface, and to the iron arms in the intermediate cylinders. The paste from the rasper falls into the first sieve, where it is strongly agitated by the brushes, while water is admitted by jets throughout the whole length of the sieve. In the intermediate cylinders *b*, the paste is stirred up with the water by the iron arms.

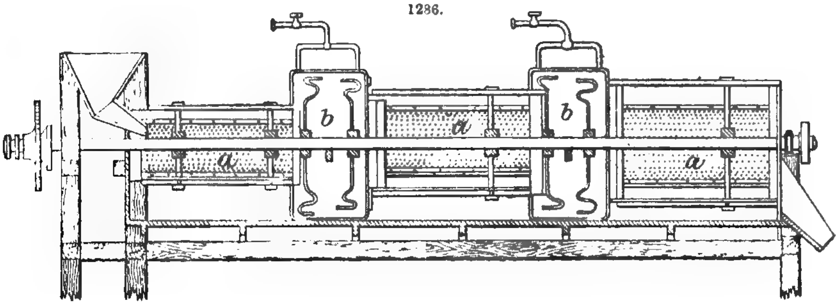
The sifted and washed starch is allowed to deposit itself in large tanks, and when this has sufficiently taken place, the water is drained off, and the deposit is again washed with water. The milky liquid is drawn off in a thin stream and passed over an inclined plane, on which the starch deposits itself at varying distances from the head of the plane, according to its quality. It still requires a washing in clean water. Sometimes centrifugal machines are employed. Fesca's is shown in plan in Fig. 1288; the drum *a*, made of ¼-in. sheet-iron, is driven by the belt *b*. Other centrifugal machines will be found described under Bleaching (pp. 495–6) and Sugar.

1285.



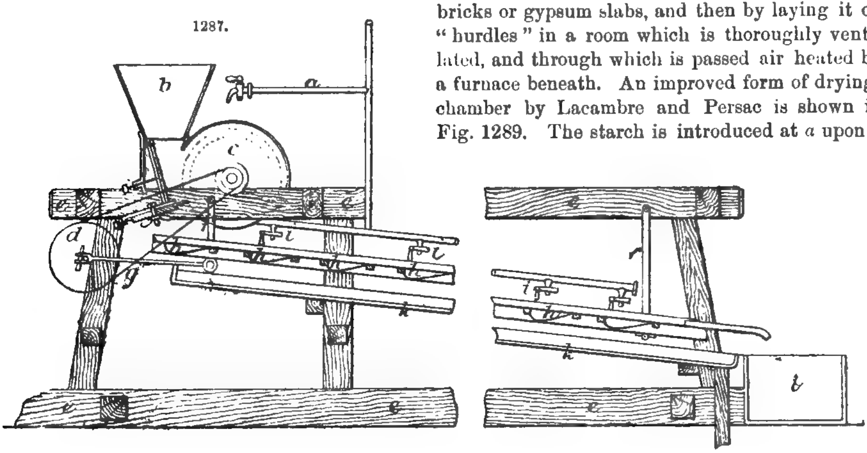
Potato-starch is largely bleached by the application of sulphuric acid; this being absolutely requisite when the potatoes are at all decayed. After the use of the sulphuric acid, any possible remaining traces must be neutralized by ammonia or milk of lime, fixed caustic alkalies being inadmissible. Chlorine is also much used for bleaching starch, usually as a solution of calcium chloride in water soured by the addition of sulphuric acid; this and some other salts cause the grains to swell, and render them soluble in cold water. Sal ammoniac is another favourite agent.

1286.



The manufactured starch finally requires drying. This is primarily effected by spreading it on bricks or gypsum slabs, and then by laying it on "hurdles" in a room which is thoroughly ventilated, and through which is passed air heated by a furnace beneath. An improved form of drying-chamber by Lacambre and Persac is shown in Fig. 1289. The starch is introduced at *a* upon a series of linen trays *b*, all of which revolve at a uniform speed, so that the starch is gradually transmitted from one to the other till it reaches the receptacle *c*, having been completely dried in its passage by encountering the hot air derived from the furnace *d*.

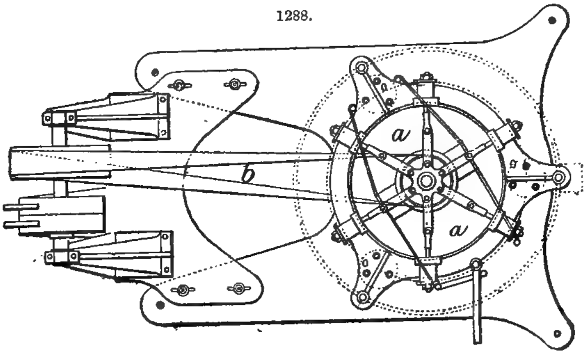
1287.



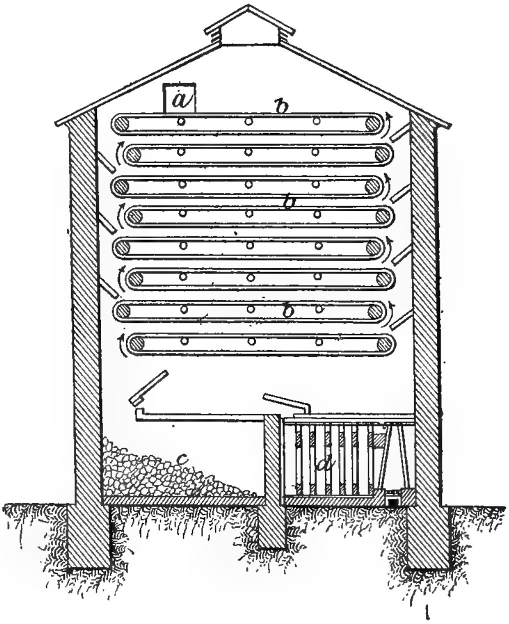
According to Schaer, potato-starch when mixed with 10 parts by weight of a mixture of 2 parts hydrochloric acid sp. gr. 1·12 and 1 part water, forms a jelly which gives off a distinct odour like that of French beans, by which it can easily be detected in presence of other starches.

Rice-starch (Fr., *Amidon de Riz*; Ger., *Reisstärke*).—The grain of the rice-plant (*Oryza sativa*) contains more starch than any other cereal, ranging between 75 and 85 per cent. The plant is raised in enormous quantities in irrigated fields in tropical and sub-tropical countries, notably India, China, Malaysia, Brazil, the S. States of America, and somewhat in Italy and Spain. Mere steeping and bruising do not suffice to separate the starch from the other components of the grain, and recourse is had to caustic alkaline lyes for the purpose. Orlando Jones' method is as follows. A lye of caustic soda or potash is made of such a strength that 350 parts of water contain 1 of alkali; 100 parts of rice are steeped in 500 parts of this dilute lye, in a vessel of copper or tin-lined iron, furnished near the bottom with a draw-off tap fitted with a gauze strainer. The liquor is drawn off after 24 hours, and twice the bulk of pure water is run in; the whole is well stirred, and the water is again drawn off. The clean grain is drained through sieves, ground in a roller-mill or between millstones, and brushed through sieves, the coarse particles which refuse to pass being reground as often as necessary. The fine rice flour is next placed in a similar vessel to the first, with 10 times the quantity of alkaline lye, and the addition of any solid matters which may have settled out from the water used to wash the whole grain; 24 hours' agitation is then given to the mass, and it is allowed 70 hours' perfect rest for subsidence. The lowest layer formed consists of heavy mineral impurities, next follow the fragments of the broken hulls, and finally (topmost) the starch, above which is a brownish-yellow turbid liquid containing the gluten in solution. This last is drawn off by a tin siphon when the operation is adjudged to be complete. The layer of starch is then mixed with water equal to twice the bulk of lye last used, the mass is allowed to subside for an hour, and the milky fluid holding the starch is siphoned off through silken sieves into a series of large vats. The residues from the previous operation are treated again and again, to make them yield the little starch they still contain. The milky liquid in the large vats deposits all its starch during 70 hours' rest. It is again washed with water, drained, and dried like wheat-starch.

1288.



1289.



Berger's process does not differ widely from the preceding. But in addition he has a plan of fermenting the steeped and ground rice for such a period as to permit the removal of the gluten by washing it out. Colman adopts somewhat the same principle, hastening the fermentation by the addition of about 15 per cent. of the sour residue from the wheat-starch manufacture. Ransford follows Jones' method pretty much up to a certain point, but keeps the grain and alkaline lye in motion, either by allowing the lye to run out at the top of the tank and pumping it back through the bottom, or by forcing it into an airtight tank at 20 lb. pressure. A part of the liquor is drained off, and the process is repeated with fresh lye. The completely saturated rice is freed from gluten by pressure through bags, and is then ground and treated for the production of the starch. The American plan differs from all the preceding. The rice is steeped with constant stirring for 18 hours in a caustic soda lye marking 1·75° B. (1·023 sp. gr.), when the dirty yellowish lye is withdrawn, and passed over long inclined tables, to separate the starch-yielding mucus from the lye. The grain, thus softened so as to be easily bruised between the fingers, is repeatedly washed, and then ground to a paste under a stream of very dilute caustic soda lye. Transferred to a vat, it is mechanically agitated for 6 hours, then left to settle for 12 hours, the lye which separates being siphoned off. The thick paste is rotated for ½ hour in a perforated centrifugal apparatus. The starch-granules arrange themselves here according to their specific gravities; the drained-off liquor may be used again for steeping fresh quantities of rice. The raw starch gathered from the centrifugal is elevated to the highest floor of the building, there stirred up with weak lye to make a "milk," which is passed through cylinder-sieves to washing-out vats on a lower floor, and thence flows to the depositing-vats on the ground floor, where it settles till firm, requiring 24–36 hours. After the clear liquor has been drawn off, the starch is stirred up with water, and passed through the centrifugals. These last should have closed sides, and it is even then doubtful whether their use is advantageous. The starch is rendered almost perfectly dry, but the pieces acquire a rough surface when broken up, and their form renders them unsuitable for making crystal starch.

Sago.—Sago is the amylaceous matter extracted from the pith of several palms; the most important are *Metroxylon Sagu* and *M. Rumphii*; the former is abundant in Sumatra, and grows wild also in Java, Borneo, Celebes, and Malacca; in the Moluccas, it is probably only cultivated; and it does not reach so far east as New Guinea and the neighbouring islands. *M. Rumphii*, which differs from *M. Sagu* in the leafstalk being armed with numerous straight brown spines 1 in. long, has a more eastern range, being abundant in the W. parts of New Guinea, the Moluccas, Mindanao, Gilolo, Ceram, and Amboyna; but is not known to occur in Timor, or westward of Celebes, and is thus absent from Sumatra and Java. Other palms yielding sago in less commercial quantity are *Phœnix farinifera* in Singapore, *Corypha Gebanga* in Java, *Caryota urens* in Mysore, *Borassus flabelliformis* and *Arenga* [*Saguerus*] *saccharifera* in other parts of India. In Malabar, a sort of sago is prepared from the seeds of *Cycas circinalis*, and in Japan from *C. revoluta*; but these do not enter into English commerce. *Metroxylon Sagu* grows in swamps, or in wet hollows on the rocky slopes of mountains; while *M. Rumphii* is a littoral species, forming dense impenetrable belts on the shores of islands. The former is readily propagated from offsets, but seed is generally unproductive. The advance in the price of and demand for the article is causing the Malays to greatly extend the plantations. For making sago, a full-grown tree is selected just before it is going to flower, which it only does when 10–15 years old, and then immediately dies.

In Ceram, it is cut down close to the ground, the leaves and leafstalks are cleared away, and a broad strip of the bark is removed from the upper side of the trunk as it lies upon the ground. This exposes the pithy matter, which is of a rusty colour near the bottom of the tree, but pure white higher up; it is about as hard as a dry apple, but with woody fibres running through it about ¼ in. apart. This pith is cut or broken down into a coarse powder by means of a tool constructed for the purpose—a club of hard and heavy wood, having a piece of sharp quartz rock firmly imbedded in its blunt end, and projecting about ½ in. By successive blows of this, narrow strips of the pith are cut away, and fall into the cylinder formed by the bark. The whole trunk is thus progressively cleared out, leaving a skin not more than ½ in. in thickness. This material is carried away (in baskets made of the sheathing bases of the leaves) to the nearest water, where a washing-machine is put up, which is composed almost entirely of the sago tree itself. The large sheathing bases of the leaves form the troughs, and the fibrous covering (coir) from the leafstalks of the young coco-nut (see p. 939), the strainer. Water is poured on the mass of pith, which is kneaded and pressed against the strainer till the starch is all set free and has passed through, when the fibrous refuse is thrown away, and a fresh basketful is put in its place. The water charged with sago-starch passes on to a trough, with a depression in the centre, where the sediment is deposited, the surplus water trickling off by a shallow outlet. When the trough is nearly full, the mass of starch, which has a slight reddish tinge, is made into cylinders of about 30 lb. weight, covered with sago leaves, and in this state is sold as raw sago. Boiled with water, this forms a thick glutinous mass, with a rather astringent taste, and is eaten with salt, limes, and chillies. Sago-bread is made in large quantities, by baking it into cakes in a small clay oven. According to Crawfurd and Blume, 500–800 lb. of sago are derived from a single tree.

In Sumatra, the felled stems are cut into pieces 3–5 ft. long, from which the outer bark is removed. After lying some days in the shade, they are taken indoors, and rasped into coarse meal with huge graters. The meal is then placed on a cloth stretched over a tub, water is poured on, and the mass is kneaded. The starch passes through with the water, collects in a receptacle, and is removed and dried, forming sago-meal.

The process of preparation in Borneo closely resembles that current in Ceram. Borneo is the head-quarters of sago-culture, the territory of Saráwak alone furnishing more than half the sago produced in the whole world. The palm flourishes on the marshy banks of the rivers all along the Saráwak coast to about 20 miles inland. Very large quantities are brought down from the Limbang, and other rivers in the interior. It is sent down in the raw state, and is manufactured into flour at two Chinese factories near Brunei, and three in Labuan. The exports from Borneo in 1879 were 20,000 tons, value about 161,432*l.* This was almost entirely sago-flour, the quantity of raw sago being very small, and of pearl still less. As seen in commerce, sago is usually in the form of grains. These are prepared by different methods in different localities, but the principle is the same in all, viz. that of mixing the meal into a paste with water, and rubbing it through suitable sieves to granulate it. It is made in a spherical form in New Guinea, according to Forrest, by allowing the sago, as it drops from the sieves, to fall into a shallow iron pot held over a fire. Blume states that in Singapore it is made by the Chinese in a similar way, the grains being constantly turned during the process. A factitious sago is prepared in Europe from potato-starch; the fraud is readily detected by the microscope.

Our imports of sago and sago-flour in 1880 were 377,025 cwt., 304,754*l.*, from the Straits Settlements; 4643 cwt., 3581*l.*, from other countries; total, 381,668 cwt., 308,335*l.* Our re-exports in the same year were: 10,954 cwt., 9224*l.*, to Denmark; 17,357 cwt., 14,391*l.*, to Germany: 14,006 cwt., 13,006*l.*, to other countries; total, 42,317 cwt., 36,621*l.* Our direct imports from Borneo were 5735 cwt., 3993*l.*, in 1876. The approximate London market values of sago are:—Pearl, small, 17–20*s.* a cwt.; medium and large, 19*s.*–21*s.* 6*d.*; flour, 16*s.*–21*s.* 6*d.*

Tapioca.—Tapioca is derived from several species of *Manihot* [*Jatropha*, *Janipha*], chiefly the bitter or poisonous (*M. utilissima*), the sweet cassava, manioc or mandioc (*M. Aipi*), and *M. Janipha.* They seem to be natives of Brazil, but are largely cultivated also in Guiana, Venezuela, W. Africa, and the W. Indies, as well as in S. India and Malaysia. The bitter kind is propagated by cuttings from the ligneous part of the stem, planted in rich dry soil. It is more productive than the sweet species, which latter will grow in almost any soil, though best in such as is suited to the former. The tubers are ready for digging up in 6–12 months, according to the variety. The volatile poison contained in the juice of the bitter kind is first removed in a measure by pressing the grated root, the operation being completed by the subsequent heating passed through. There are two modes of preparing this starch. In the "wet" method, the grated root is placed in water for 4–6 days, then kneaded with water, and pressed to extract the juice. The fecula is sifted and baked in earthen ovens, some fresh manioc paste, which has fermented, being always added. In the "dry" process, the root is rasped by hand, water is added, and it is put to be pressed; after drying and sifting, it is baked. The fecula deposit is washed 3 times and sun-dried. The collected starch, heated on iron plates, becomes partially cooked, and agglomerates in small, hard, irregular lumps, constituting tapioca. In British Guiana, the juice is expressed from the grated root by means of a cylindrical squeezer, called a *matapi*, made from the *ita*-palm (*Mauritia flexuosa*). By attaching one end of the filled bag to a beam, and suspending a weight from the other end, the contents of the bag are compressed by its elongation, and the juice runs out. Pearl tapioca is likewise factitiously prepared from potato-starch. The concentrated juice of the bitter cassava is the basis of the well-known W. Indian sauce called "pepper-pot."

The culture of the plant is inexpensive, and the product is highly remunerative, so that the growth of the plant is becoming very general throughout the tropics. Brazil exported about 7 million *litres* (of 1¾ pints), value 26,050*l.*, in 1871. Dominica exported 246 bush., 63*l.*, in 1872; 2242 bush., 324*l.*, in 1878. Brunei (Borneo) shipped 413 dol. worth to Singapore in 1879. The approximate London market values are:—Rio, 3–6*d.* a lb.; Penang and Singapore, 2⅛–3½*d.*; flour, 1⅜–2⅝*d.*; pearl, 18–30*s.* a cwt. Rio tapioca is whiter than that of Bahia.

Wheat-starch (FR., *Amidon de Blé*; GER., *Weizenstärke*).—The ripe grain of the wheat-plant (*Triticum vulgare*) contains 50–75 per cent. of starch. There are three chief methods for preparing wheat-starch, based on different principles:—(1) By acetous fermentation, (2) without fermentation, (3) from flour.

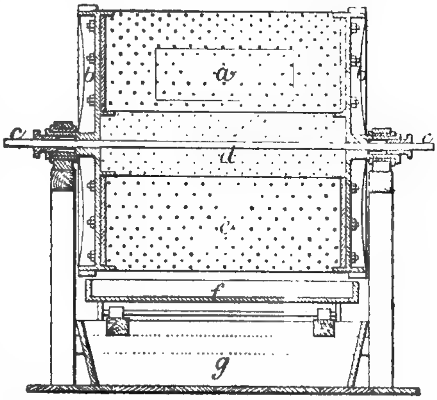
The first plan, which is still in wide use where flour-mills are taxed, labours under the disadvantages that the gluten is destroyed for all practical purposes, and that noxious vapours and foul liquids are largely produced. The wheat is first soaked in "steeping-troughs," capacious tanks of wood, iron, masonry, or concrete, arranged so as to be readily supplied with clean water, and as readily drained of foul liquors, and maintained at a temperature of 12½°–15° (54½°–59° F.). The tank has a strainer-tap for drawing off the foul liquid, and a manhole near the bottom for withdrawing the grain. The tank is half-filled with pure soft water; some of the grain is introduced, and thoroughly stirred up; the hulls, empty grains, and rubbish are skimmed off. This is repeated with new quantities of grain, and water is let in till it rises 2–3 in. above the grain. This water is generally used at a temperature of 10°–12½° (50°–54½° F.), but the operation may be much hastened by employing it at 30°–38° (86°–100½° F.). The duration of the steeping depends much upon the temperature, and upon the character of the water and grain respectively, but commonly amounts to four days in summer and 10–11 in winter. The foul water is drained off, and the soaked mass is washed clean by running in fresh water, and allowing it to drain off for several hours. The grain is then withdrawn at the manhole for bruising. It is necessary to watch that the water does not become sour by the fermentation of extracted matters.

The bruising is very simply performed in a roller mill, the iron rods being adjustable, and a smaller roll revolving above, and serving to regulate the feed. The mill must be set so that it will bruise every grain without crushing the starch granules.

The bruised grain is conveyed for fermentation to large oaken cisterns, which, when new, require to be filled with boiling water for three days to extract the tannic acid. For fermentation, the grain is stirred up with pure water in summer, or soured water in winter, the temperature is maintained at about 20° (68° F.), and the operation lasts some 14 days. During its continuance, the mass is well stirred up. Finally the scum subsides, the surface becomes covered with a fungus (*Penicillium glaucum*), and the mass is " ripe." The result of the fermentation is that the gluten has been so far decomposed as to liberate the starch granules; care must be taken to prevent its overstepping this limit, and affecting the starch granules themselves.

The impure liquor is drawn off from the starch mass, and the latter is transferred to washing-drums (Fig. 1290) for evaporating the starch from the associated impurities. The side-walls *b* of the drum are of wood with iron spokes, the drum itself being a perforated copper plate *e*; a perforated pipe *c* passes through the stuffing-boxes of the drum, and is surrounded by a second casing *d*, also perforated. The drum is emptied and filled by the door *a*. The starch-milk flows from the drum into the box *f*, which runs on rollers, and thence into the depositing-tank *g*.

1290.

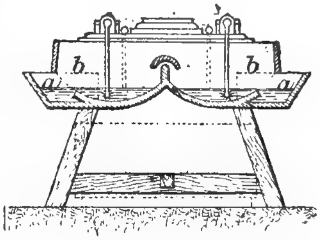


Here the gradual separation of the starch takes place under the influence of agitation and subsequent rest. All but the starch, which forms the lowermost layer, is removed. The starch is then passed through very fine hair sieves, and again stirred up with pure water, and again allowed to deposit after some agitation. It is more convenient to effect the sifting under water. The final deposition takes place in oblong troughs, with convenient taps for letting off the liquids. The refining is not carried beyond the point when the starch ceases to show an acid reaction on litmus-paper. The washing is frequently done in centrifugal machines. Lastly, the starch is dried, first partially by laying the cakes under bricks or gypsum slabs, or by means of air-pumps, and completely in a drying-room at 60° (140° F.).

In preparing wheat-starch without fermentation, the grain is steeped, bruised, and washed, the last operation being best done in a centrifugal machine. The process is not a general one, in spite of its affording the gluten as a by-product.

The preparation of starch from wheat-flour (Martin's method) has many advantages over the ordinary plan. The flour is kneaded into a stiff dough with water, and, after one or two hours, the dough is washed in a fine sieve under a jet of water till all the starch has escaped as a milky fluid. The washing is best effected by a machine such as is shown in Fig. 1291. The troughs *a* contain water, and are replaced at *b* by wire cloth drawn over a wooden frame. Grooved wooden rollers are made to move across the bottom of the troughs, while constant jets of water play upon the dough. About one hour suffices for liberating the starch from 2 lb. of dough. The starch-milk flows off by a pipe into a receiver. The gluten is freed from surplus water by kneading under the rollers, and is then removed for utilization as food.

1291.



Bibliography.—J. Wiesner, 'Die Rohstoffe des Pflanzenreiches' (Leipzig: 1873); R. J. Bernardin, 'Classification de 250 Fécules' (Ghent: 1876); P. L. Simmonds, 'Tropical Agriculture' (London: 1877); C. Scheibler, 'Stärkemehl Industrie' (in A. W. Hofmann's 'Chemische Industrie,' III. Heft, Brunswick: 1877); Flückiger & Hanbury, 'Pharmacographia' (London: 2nd ed., 1879); Frankel & Hutter, 'Starch, Glucose, &c.' (Philadelphia: 1881); F. Rehwald, 'Stärke-Fabrikation, &c.' (Leipzig); Bentley & Trimen, 'Medicinal Plants,' pp. 265, 266, 278 (Lond.: 1875–80); Pereira's 'Materia Medica,' 5th ed., Vol. ii., part 1.

SUGAR (Fr., *Sucre*; Ger., *Zucker*).

The term "sugar" was originally employed and intended to classify all substances having a sweet flavour, and thus came to be used almost indiscriminately for cane-sugar, fruit-sugar, sugar (acetate) of lead, and other bodies possessing that property. At present, in a general sense, it is reserved almost exclusively to denote cane- and beet-sugar (true crystallizable sugar). In chemistry, the word "sugar" is applied generically to a large class of organic bodies intermediate between starch and alcohol, termed "carbohydrates," each having 6–12 atoms of oxygen and hydrogen combined in the proportion to form water; they are nearly allied to, and may be considered as derivatives of, the hexatomic alcohols ($C_6H_{14}O_6$), of which, mannite may be taken as a type. Indeed, mannite, which can hardly be strictly classed as a true sugar, may be artificially formed from glucose ($C_6H_{12}O_6$) by treatment with sodium amalgam, the glucose thereby taking up 2 atoms more of hydrogen, and becoming converted into mannite:—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} + 2\,H = \underset{\text{Mannite.}}{C_6H_{14}O_6}$$

Although the hexatomic alcohols are not to be regarded as true sugars, still, as each of them possesses a marked saccharine flavour, and presents some of the other characteristics of the true sugars, it will be convenient and instructive to include them in the subjoined tabular classification:—

CARBOHYDRATES.

Isomeric Saturated Hexatomic Alcohols. $C_6H_{14}O_6$.	Isomeric Glucoses. $C_6H_{12}O_6$.	Isomeric Saccharoses. $C_{12}H_{22}O_{11}$.
Mannite, mannitol.	Sucro-dextrose, dextrose, glucose, diabetic sugar.	Cane-sugar, saccharose, sucrose.
Dulcite, dulcitol.	Sucro-lævulose, lævulose, lævo-glucose.	Milk-sugar, lacton, lactose, lactine.
Isodulcite, isodulcitol.	Lactose, galactose.	Starch-sugar, amylon, maltose.
Sorbite, sorbitol.	Arabinose, pectinose.	Mycon, mycose, trehalose.
Pinite, pinitol.	Eucalyptose.	Eucalypton, melitose.
Quercite, quercitol.	Sorbin.	Meleziton, melezitose.
Inosite, inosol.		Parasaccharose.
Dambose.		Synanthron, synanthrose.
Bornesite.		
Dambonite.		

The properties by which the members of these groups may be distinguished are mainly:—(1) By boiling with acids (even dilute), the hexatomic alcohols and the glucoses are but little affected, while the saccharoses are converted into glucoses; (2) the varying powers possessed by many of their solutions, particularly the glucoses and saccharoses, in rotating the vibration-plane of a ray of polarized light; (3) the tendency of the glucoses to enter into fermentation, while the hexatomic alcohols are unfermentable, and the saccharoses are either unfermentable, or only partially fermentable and with great difficulty; most of the last, however, are converted into glucoses by the action of ferments, some of which, such as diastase (a principle formed during the germination of seeds) and synaptase (a principle found in almonds and other fruit-kernels), have special effects. The saccharoses are also converted into glucoses by the saliva, and the juices of the stomach and intestines; and some, as cane-sugar, merely by prolonged heating or boiling in water. Some other ferments, such as *Torula cerevisiæ* and *Penicillium glaucum*, seem to possess the property of converting some saccharoses into glucoses, before promoting the special fermentations produced by their propagation. The fermentable sugars ($C_6H_{12}O_6$) which are capable of direct vinous fermentation are invert sugar (a mixture of dextrose and lævulose), dextrose, lævulose, galactose, maltose.

The members of the first group (hexatomic alcohols) demand no further consideration here. The most important commercially is mannite (see Drugs—Manna, pp. 817–8). The members of the second group (isomeric glucoses) will be spoken of generically at greater length, and the principal ones are specially dealt with under Honey (pp. 1127–30), Drugs—Manna (p. 810), Fruit (pp. 1022–9), Beverages—Wine (pp. 432–50), and sub-sections of the present article.

Invert sugar ($C_6H_{12}O_6$) can be produced from crystallizable sugar by the action of acids, diastase, heat, salts, &c. It is easily fermentable, forms salts with metallic bases, is found in the juices of many plants, and is present in very large proportion in the juice of unripe sugar-cane; it is manufactured on a large scale from grain or starchy materials by treatment with a mineral acid, and conversion with high-pressure steam (see Starch-sugar); as thus prepared, it is uncrystallizable, of a slightly sweetish flavour, and can be concentrated to a thick jelly or to a solid state; heated with a solution of cane-sugar, it converts nearly its own weight of that substance into the uncrystallizable form; with alkalies, it darkens in colour, and forms soluble salts with them; it reduces an alkaline solution of a cupric salt; as a syrup, it is almost colourless, and, in the solid form, the colour varies according to the care taken in its preparation. The two bodies of which it is composed, namely dextrose or dextro-glucose and lævulose or lævo-glucose, differ in rotatory power, and in other particulars; they are, however, seldom met with in a separate state.

Dextrose ($C_6H_{12}O_6$) rotates a ray of polarized light to the right. It may be obtained in the form of needle-shaped crystals by the evaporation of an alcoholic solution; when freshly prepared, its rotatory power is 112°, but after standing for some time, or immediately on heating, the rotation sinks to 56°, and remains constant: it is insoluble in ether, soluble in alcohol, and gives no coloration when mixed with concentrated sulphuric acid; with alkalies, on the application of heat, it turns brown; it reduces an alkaline solution of a cupric salt, and forms with metallic bases, compounds called glucosates; when heated to 170° (338° F.), it gives off one atom of water; by increasing the temperature, it turns brown, and is subsequently converted into caramel.

Lævulose is isomeric with dextrose, but rotates a ray of polarized light to the left; its molecular rotatory power, which varies with the temperature, according to Dubrunfaut, is $[\alpha]j = -53°$ at 90° (194° F.), $-79 \cdot 5$ at 52° (125·6° F.), -106 at 14° (57·2° F.). It is a colourless, uncrystallizable syrup; on the application of heat, it behaves much in the same way as dextro-glucose. It may be prepared by inverting cane-sugar with hydrochloric acid, and adding excess of calcic hydrate; the liquid after some time solidifies, and the solid mass, when submitted to pressure, yields a solution of a calcium salt of dextro-glucose together with calcium chloride; after washing the cake of lævo-glucose with water, and treating with oxalic acid, a solution of lævo-glucose is obtained.

Maltose, according to O'Sullivan, is a crystalline body yielding 50 per cent. of its weight of alcohol when fermented with yeast. It is formed by the action of malt-extract on starch; its specific rotatory power is twice that of cane-sugar (147·6). 100 parts correspond to 77·32 of cupric oxide, being equal to 65 parts of invert sugar. By boiling with acids, it is converted into dextrose.

Those members of the third group (isomeric saccharoses) which are objects of manufacture will be described in detail under their special heads; others are dealt with under Drugs—Ergot, p. 810, Manna, p. 818.

It may here be explained that "barley-sugar" is pure sugar melted by heat, and allowed to solidify to an amorphous mass instead of crystallizing. "Sugar-candy" is a solution of sugar crystallized by very slow evaporation, the crystals being unusually large, and centred around threads suspended in the liquid for the purpose of forming nuclei. "Molasses" is the dark-coloured, impure liquid, consisting of a mixture of crystallizable and uncrystallizable sugar, coloured by caramel (see pp. 598–9), and containing the greater part of the organic matters separated in the processes of making and refining cane- and beet- sugars. "Syrup" or "golden syrup" is the molasses obtained by washing and "machining" the higher classes of refined sugar. "Glucose" is applied commercially only to artificial starch-sugar; in analysis, it signifies all uncrystallizable sugar found in cane-sugars: to avoid confusion, the term "uncrystallizable sugar" will be employed throughout this article to denote all forms of uncrystallizable or very slightly crystallizable sugar—(the very weak crystallizing power of dextrose and lævulose causes them to be called *un*-crystallizable)—met with or produced in the course of preparing crystallizable sugar, and the special terms glucose, starch-sugar, will be reserved for their special application. The commercial sugars, whose production and manufacture will receive detailed description in this article, will take the following order:—Beet-sugar, Cane-sugar, Maple-sugar, Melon-sugar, Milk-sugar, Palm-sugar, Sorghum- and Maize-sugar, Starch-sugar and other Glucoses. These will be followed by sections on Sugar-refining, Summary of Patents, Analysis, Production and Commerce, Bibliography.

Beet-sugar (FR., *Sucre de Betteraves*; GER., *Rübenzucker*). CULTIVATION.—The beetroot (*Beta vulgaris*), indigenous to Europe, is cultivated in France, Germany, Belgium, Holland, Scandinavia, Austria, Russia, and to a very small extent in England, and recently established in Canada, the United States, and New Zealand. There are many varieties. The most important to the sugar-maker is the white Silesian, sometimes regarded as a distinct species (*B. alba*); it shows very little above ground, and penetrates about 12 in.; it has a white flesh, the two chief forms being distinguished by one having a rose-coloured skin and purple-ribbed leaves, the other a white skin and green leaves. Both are frequently grown together, and exhibit no marked difference in sugar-yielding qualities.

Good sugar-beets possess the following broad characteristics:—(1) Regular pear-shaped form and smooth skin: long, tapering, carrot-like roots are considered inferior; (2) white and firm flesh, delicate and uniform structure, and clean sugary flavour: thick-skinned roots are spongy and watery; those with large leaves are generally richer; (3) average weight 1½–2½ lb., neither very large nor very small roots being profitable to the sugar-manufacturer; as a rule, beets weighing more than

3½ lb. are watery, and poor in sugar; and roots weighing less than ¾ lb. are either unripe or too woody, and in either case yield comparatively little sugar; the sp. gr. of the expressed juice, usually 1·06–1·07, even reaching 1·078 in English-grown roots, indicating over 14 per cent. of crystallizable sugar, is the best proof of quality; juice poor in sugar has a density below 1·060; (4) in well-cultivated soil, the roots grow entirely in the ground, and throw up leaves of moderate size.

The improvement of the sugar-beet has long been studied by Continental agriculturists. The comparative values of the chief new sorts shown at the Paris Exhibition may be thus tabulated, premising that the figures given are not attained on a working scale:—

Name.	Gross yield per acre.	Sugar in 1 gal. of juice.	Sugar yield per acre.	Working yield of Sugar.	
				Per ton.	Per acre.
	lb.	lb.	lb.	lb.	lb.
German	50,776	1·54	6925	226	4541
Green-neck..	67,936	1·42	8496	177	4775
Rose-neck	65,560	1·47	8562	186	4835
Grey-neck	72,072	1·32	8333	152	4417
Vilmorin's	36,168	1·90	6103	296	4144

The last-named is most esteemed where the duty is levied on the roots (Germany and Russia); it gives 15–18 per cent. of extremely pure juice.

Composition of the Roots.—Internally the root is built up of small cells, each filled with a juice consisting of a watery solution of many bodies besides sugar. These include several crystallized salts (most of which are present in minute traces only), such as the phosphates, oxalates, malates, and chlorides of potassium, sodium, and calcium, the salts of potash being by far the most important; and several colloid bodies (albuminous [nitrogenous] and pectinous compounds); as well as a substance which rapidly blackens on exposure to the air. The greater part of the sugar in ripe beets is crystallizable, and, when perfectly pure, is identical in composition and properties with crystallized cane-sugar; but it is more difficult to refine this sugar so as to free it from the potash salts, and commercial samples have not nearly so great sweetening power as ordinary cane-sugar. Beets contain no uncrystallizable sugar: the molasses produced in beet-sugar manufactories is the result of changes which cannot be entirely avoided in extracting the crystallizable sugar.

Following are analyses by Voelcker of roots grown near Lavenham, Suffolk:—

Description	Green top, white skin.	Red top, rose-coloured skin.	White pear-shaped root.	Long red root.	Long red root.	Pear-shaped white root.	Small red top.	Pear-shaped white root.
Weight of root ..	2¾ lb.	2 lb. 4½ oz.	1½ lb.	2 lb.	1¾ lb.	2 lb. 5 oz.	1 lb. 4¾ oz.	2 lb. 12¼ oz.
Sp. gr. of juice ..	1·0637	1·0689	1·058	1·0612	1·0628	1·0589	1·0659	1·0643
At a temp. of.. ..	64° F.	64° F.	62° F.	62° F.	..	..	58° F.	58° F.
Moisture..	83·11	82·72	83·03	83·43	82·70	82·27	81·76	83·34
Albuminous compounds *	1·25	1·44	1·71	1·53	1·23	1·08	2·13	2·12
Crude fibre (pulp)..	3·43	3·38	4·31	3·49	3·60	3·73	3·77	3·04
Crystallizable sugar	10·51	10·94	9·31	10·04	10·72	11·14	10·55	9·74
Pectin, colouring matter, &c.	0·63	0·45	0·60	0·50	0·68	0·74	0·70	0·52
Mineral matter (ash)	1·07	1·07	1·04	1·01	1·07	1·04	1·09	1·24
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	0·200	0·231	0·275	0·245	0·197	0·173	0·341	0·340

Climate.—The mean temperature of the Continental beet-growing districts, and of those localities in England where beets may be cultivated for sugar-making purposes, is about 16½°–18° (62°–65° F.). The formation of the sugar is favoured not so much by a hot summer as by dry weather and unclouded sky during autumn: hence the root succeeds better in N. France and N. Germany than in Central France and S. Germany; hence also the prospects of remunerative culture in Canada and New Zealand, and the failure in Australia. Nothing is so conducive to heavy crops as an abundance of rain during the first 2 months' growth of the plant. It would thus appear that the E., S.-E. and N. counties of England, with many localities in Scotland, and a portion of Ireland, are, so far as climate is concerned, well suited to the cultivation of the sugar-beet; but it has hitherto been very little encouraged by agriculturists.

Soil.—The best soil for beet contains a fair proportion of organic matter, is neither too stiff nor too light, and crumbles down into a nice friable loam; it must be capable of being cultivated to a depth of at least 16 in. The subsoil should be thoroughly well drained, and rendered friable by autumn-cultivation and free admission of air. A deep friable turnip-loam, containing fair proportions of clay and lime, appears to be the most eligible land for sugar-beets. Lime is a very desirable element. Well-worked clay-soils, especially calcareous clays, are well adapted, if properly drained and of sufficient depth. Peaty soils and moorlands are quite unsuitable, as well as lands which are too dry, like the thin gravelly soils resting on siliceous gravel sub-soils, or too wet and cold, like many of the thin soils above impervious chalk marl.

Speaking generally, the best soils for sugar-beet are precisely those on which other root-crops can be grown to perfection, that is, land which is neither too heavy nor too light, which has a good depth, is readily penetrated by the roots, and naturally contains lime, potash, clay, and sand, as well as organic matter, in such proportions as in good friable clay-loams. An analysis of the soil should be made previous to planting it with the sugar-beet, as the salts presented in solution in the soil will pass into the juice, and greatly interfere with the processes of sugar manufacture. Certain soils may be at once indicated as unsuitable: they are clover-land, recent sheep-pastures, forest-land grubbed during the preceding 15 years, the neighbourhood of salt-works, volcanic and saline soils of all kinds. The beet requires a certain supply of potash and soda salts in the soil, but if these are present in excess, as in recent forest-land, the juice does not work well, nor give its proper yield of sugar.

Manures.—Sugar-beets should be grown with as little farmyard manure as possible; when dung has to be used, as in the case of very poor soils, it should be applied in autumn, or as early as possible during the winter months. The effect of heavy dressings of animal nitrogenous matters or ammoniacal salts, is to produce abundance of leaves, and big watery roots; the latter are comparatively poor in sugar, and contain potash salts derived from the animal matters, which greatly interfere with the extraction of sugar in a crystallized state. Common salt, and saline manures in general, though useful in moderate doses (2–3 cwt. per acre on light soils), should be avoided on the majority of soils, for sugar-beets grown on soils highly manured with common salt produce juice largely impregnated with salt, which is dreaded by the manufacturer even more than albuminous impurities, and nearly as much as excess of potash salts.

If the land is in good condition, containing sufficient available nitrogen to meet the requirements of the crop, neither guano nor sulphate of ammonia should be used. They largely increase the weight of the produce per acre; but heavy crops are generally poor in sugar, and furnish a juice that presents much difficulty to the manufacturer. If the land is very poor, and if farmyard manure cannot be obtained and be applied in autumn, 3–4 cwt. of Peruvian guano, or 2 cwt. of sulphate of ammonia, mixed with 2 cwt. of superphosphate of lime, per acre, may be sown broadcast in autumn, and 2 cwt. more of superphosphate may be drilled in with the seed in spring. Superphosphate of lime and bones are excellent for sugar-beets, and never injure the quality of the crop, like the indiscriminate use of ammoniacal manures. On light soils, in which potash is often deficient, the judicious use of potash salts has been found serviceable, but only in conjunction with superphosphate and phosphatic guanos.

Analyses of sugar-beet ash show that this crop takes from 1 acre of land:—Potash, 161·92 lb.; nitrogen, 105·60; phosphoric acid, 40·48; lime, &c., 31·68. The injurious consequences of a heavy spring-dressing of dung for sugar-beets are shown in the annexed analyses, representing the composition of 2 very large white Silesian beets grown in Suffolk:—

	A.	B.
Weight of root	11 lb. 6 oz.	6 lb. 8 oz.
Sp. gr. of juice at 18° (65° F.)	1·0431	1·0553
Moisture	92·58	88·13
Albuminous compounds *	1·40	2·16
Crude fibre [pulp]	1·73	2·74
Crystallizable sugar	2·22	4·82
Pectin, &c.	0·47	0·44
Mineral matter [ash]	1·60	1·71
	100·00	100·00
* Containing nitrogen	0·225	0·347

Sowing.—The best time for sowing beetroot in England is the beginning or middle of April. If sown too early, the young plants may be partially injured by frost; if later than the first week in

May, the crop may require to be taken up in autumn, before it has had time to get ripe. About 10–12 lb. of seed is required per acre. As regards the width between the plants, generally speaking, the distance between the rows and from plant to plant should not be less than 12 nor greater than 18 in. Should the young plants be caught by a night's frost, and suffer ever so little, it is best to plough them up at once and re-sow, for they are certain to run to seed, and are then practically useless for the manufacture of sugar. Sugar-beets require to be frequently horse- and hand-hoed. As long as the young plants are not injured, the application of the hoe from time to time is attended with great benefit to the crop. It is advisable to gather up the soil round each plant, in order that the head may be completely covered with soil. Champonnois' researches point to the advantage of planting in ridges, by which the supply of air to the roots is greatly facilitated.

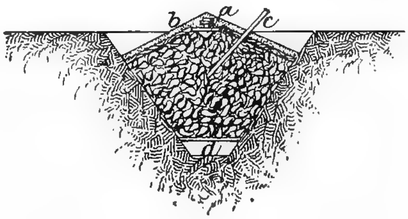
On the Continent, the conditions best calculated to ensure the roots possessing the characters most desirable from a sugar-maker's point of view have been much studied. They are chiefly as follows:—(1) Not to sow on freshly-manured land: it is eminently preferable not to manure for the beet crop, but to manure heavily for wheat in the preceding year; (2) not to employ forcing manures, nor to apply manure during growth; (3) to use seed from a variety rich in sugar; (4) to sow early, in lines 16 in. apart at most, the plants being 10–11 in. from each other: there will then be 38,000 beets on an acre, weighing 21–28 oz. each, or 52,800–70,400 lb. per acre; (5) to weed the fields as soon as the plants are above ground, to thin out as early as possible, and to weed and hoe often, till the soil is covered with the leaves of the plants; (6) never to remove the leaves during growth; (7) finally, not to take up the roots, if it can be avoided, before they are ripe, the period of which will depend upon the seasons.

Good seed may be raised by the following means. The best roots, which show least above ground, are taken up, replanted in good soil, and allowed to run to seed. This seed is already good; but it may be further improved by sowing it in a well-prepared plot possessing all the most favourable conditions; the resulting plants are sorted, set out in autumn, put into a cellar, and in the spring, before transplanting, those of the greatest density, and which will give seeds of the best quality, are separated. These are transplanted at 20 in. between the rows and 13 in. between the feet, which are covered with about 1½ in. of earth. Finally they are watered with water containing treacle and superphosphate of lime, as recommended by Corenwinder.

Harvesting.—Sugar-beets must be taken up before frost sets in. When the leaves begin to turn yellow and flabby, they have arrived at maturity, and the crop should be watched, that it may not get over-ripe. If the autumn is cold and dry, the crop may be safely left in the ground for 7–10 days longer than is needful; but should the autumn be mild and wet, if the roots are left in the soil, they are apt to throw up fresh leaves, and nothing does so much injury. In watching the ripening of the crop, a good plan is to test the sp. gr. of the expressed juice. A root or two may be taken up at intervals, and reduced to pulp on an ordinary hand-grater, the juice obtained by pressing the pulp through calico, and the density observed by a hydrometer. As long as the gravity of the juice continues to increase, the crop should be left in the land. Good sugar-yielding juice has a sp. gr. of about 1·065, rising to about 1·070. Immature roots, cut across, rapidly change colour on the exposed surface, turning red, then brown, and finally almost black. If newly-cut slices turn colour on exposure, the ripening is not complete; but if they remain some time unaltered, or turn only slightly reddish, they are sufficiently ripe to be taken up. The crop should be harvested in fine, dry weather. In order that the roots may part with as much moisture as possible, they are left exposed to the air on the ground before being stacked, but not for longer than a few days, and they need to be guarded against direct sunlight. Perhaps the best plan is to cover them loosely with their tops in the field for a couple of days, then trim them, and at once stack them.

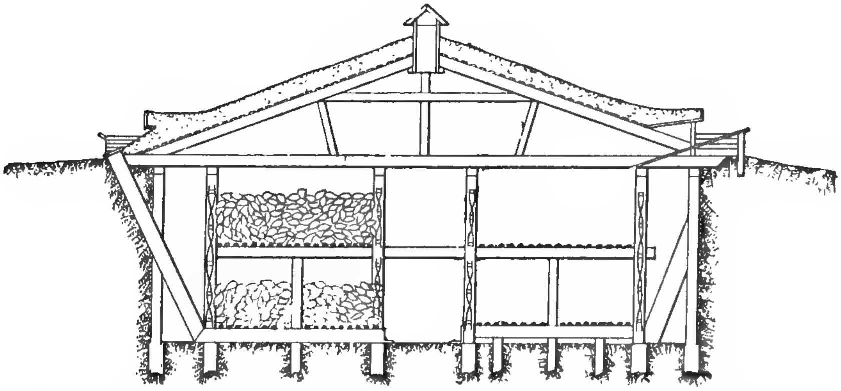
Storing.—For storing roots, especial care should be taken to prevent their germinating and throwing out fresh tops, which is best done by selecting a dry place for the storage ground. They may be piled in pyramidal stacks, about 6 ft. broad at base, and 7 ft. high. At first, the stacks should be thinly covered with earth, that the moisture may readily evaporate; subsequently, when frosty weather sets in, another layer of earth, not exceeding 1 ft. in thickness, may be added. This is essentially the method generally adopted in this country for storing potatoes and mangold.

1292.



In continental Europe and Canada, extra precaution is necessitated by the rigorous climate. In S. Russia, the plan shown in Fig. 1292 is sometimes used. The beets are disposed completely below the surface of the soil, in a trench dug with sharply sloping sides. At about 15 in. from the bottom, is an openwork floor of reeds, on which the beets are piled to within a few inches of the level of the exterior soil. On the top, and following the apex of the heap, is laid a triangular ridge-piece *a*, for the purpose of facilitating evaporation. The whole is covered with a layer *b* of straw and fine earth, the thickness of which is varied according to the indications of the thermometer *c* placed in the centre of the mass. Between the floor of the trench and the openwork floor is a space *d*, communicating with two vertical channels leading to the outer air, thus providing ventilation. The outlets of the channels can be opened and closed at will. The Russians also often employ regular cellars, as shown in Fig. 1293. The structure consists of two storeys, covered with a bed of earth, each furnished with a floor of hurdles or open planking, on which the beets are piled to the depth of about 1 yd. Lateral passages facilitate ventilation, and openings in the roof permit the heated air to escape. The cost of erecting these cellars is heavy, but there is great saving of labour in storing the beets, as it suffices to simply pile them up on the floors. Moreover, the arrangement permits the examination of the contents beyond the indications of a thermometer; and enables any portion to be removed, even during snowy weather.

1293.



Diseases and Enemies.—The insects injurious to beet are principally three,—the beet carrion-beetle, the beet-fly, and the silver-Y moth. The beet carrion-beetle (*Silpha opaca*) gnaws away the leaves till the fibres alone remain, but the roots escape. The egg is commonly laid in putrid matter. The attacks of the grub last from about the 3rd week in May to the end of June; no damage seems to be done by the summer brood of beetles. Remedies are:—(1) sprinkling the plants with a mixture of 1 bush. gas-lime, 1 bush. quick-lime, 6 lb. sulphur, and 10 lb. soot, made into a fine powder, and applied while the dew is on the leaf, this quantity sufficing for about 2 acres; (2) the substitution of superphosphate of lime for farmyard dung; (3) the application of dung, when used, in the autumn instead of the spring.

The beet- or mangold-fly (*Anthomyia betæ*) damages the crops by the attacks of its voracious legless maggots, which feed on the pulp of the leaves, and reduce them to a dry skin. Their worst effects are seen on peat and fen lands, and in wet seasons. A dressing of superphosphate seems to be effectual.

The silver-Y moth (*Plusia gamma*), extending from Abyssinia to Greenland, and met with in China, Siberia, and N. America, occasionally does great damage to the Continental beet-crops, while in the caterpillar state. The latter are large, and consume the leaves rapidly. Dustings of caustic lime, soot, or salt, and drenchings of liquid manure or simple water, are beneficial.

Extraction. Purchase.—In the beet-sugar industry, the manufacturer very seldom grows the whole of the beet that he works up, though he almost invariably raises a considerable proportion. The basis upon which the manufacturer purchases from the grower is a matter of importance to both. It is the interest of the manufacturer to base payment upon the quantity of sugar delivered in the roots. To buy and sell on the weight of roots is unfair to both, taking no account of the quality of the article, and removing all inducement to grow the most highly saccharine kinds. To make an average analysis of a crop, would be very inconvenient; but as the juice is denser according as it is richer in sugar and poorer in other salts, it has been customary to base the value on this, taking for foundation a sp. gr. of 1·055 (7·27° B.), called 5·5 degrees, and raising the price proportionally above that figure. It has likewise been suggested that the price should be subject to a corresponding reduction for juice below 5·5, but this is generally deemed unfair to the grower, as only arising through unpropitious seasons and other causes not within his control.

The "Société Centrale de l'Agriculture du Pas-de-Calais" proposes the following scale:—

Density.	Sugar Yield.	Price.	
		Per 1000 Kilo.	Per Ton.
sp. gr.	per cent.	fr.	s. d.
1·045	8	16	12 10
1·050	9	18	14 6
1·055	10	20	16 2
1·060	11	21	17 0
1·065	12	22	17 10

An objection to this scale is that the progressive value is not geometrically increased with the greater richness, whereas the yield of sugar is known to be augmented disproportionately in rich juice. Thus, to produce 100 lb. of sugar will require: 1333 lb. of beetroot at 12½ per cent.; 1593 at 11; 2213 at 9. In other words, while 620 lb. are needed to compensate for the difference between 9 and 11, only 260 are necessary to counterbalance that between 11 and 12½.

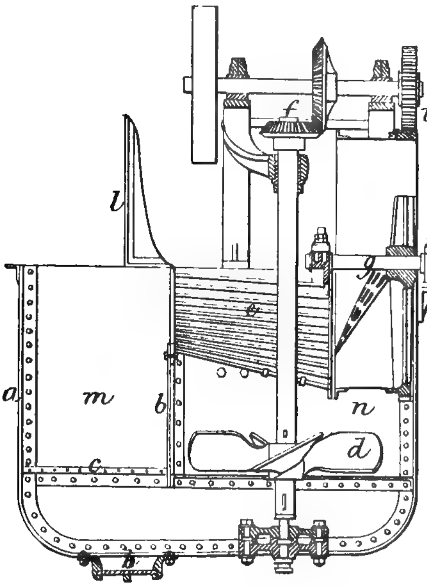
When the roots are delivered at the factory, after having been deprived of leaves, rootlets, and necks (the portion growing above ground), they are weighed, and a "tare" is deducted for earth, badly-trimmed necks, and other useless matters. This is the point at which the manufacturers' and cultivators' interests clash; in Germany, this weight is also the basis of taxation of the industry. When the crop is paid for according to the density of the juice, a certain number of roots are selected as a sample, their pulp is rasped up, and the juice is expressed and tested by a hydrometer. Several instruments have been devised for rapidly dealing with sufficient roots for this purpose, the most important being those of Possoz, Violette, and Thomas.

Transport.—The transport of the roots from the fields to the factory may be performed by rail, road, or river, where such facilities exist; but the rope-tramway system presents many advantages, as it abstracts nothing from the land under cultivation, is very cheap, and can be moved about as circumstances require. The labour, cost, and difficulty of conveying enormous quantities of roots to the factory, where the juice is to be utilized and the pulp returned, have drawn attention to means of transporting the juice alone, which has been independently extracted on the farm producing the beet. A few years since, Linard, of Cambray, introduced a plan of sending the juice to a central factory by means of an underground system of piping, which is gaining favour in France and Belgium. A single factory is thus enabled to work up what would otherwise have to be distributed among several factories, effecting at the same time great economy of transport, fuel, plant, and labour. The juice, obtained by any of the methods to be described later, is received in gauge-tanks, treated with 1 per cent. of lime, and pumped into the cast-iron subterranean conduit, capable of withstanding a pressure of 15 atmos., and of a diameter (varying with the distance) of 2½–5 in. The juice is received at the central factory in large store-tanks. There is no apparent effect upon the pipes after several years' constant use. The set at Cambray takes the juice produced by 10,250 acres of beet.

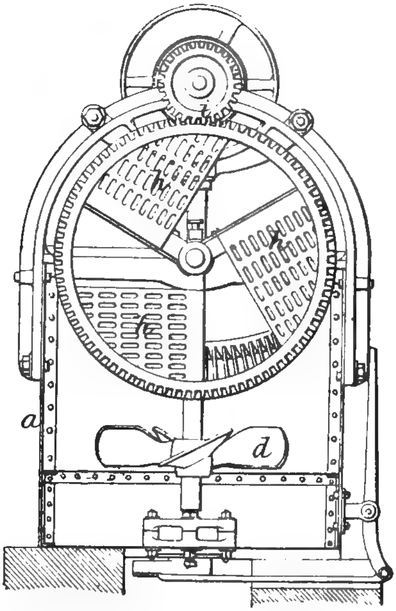
Cleansing the Roots.—The first step towards extracting the juice from the roots is to free the latter from foreign matters. With this object, the roots are conveyed to a room capable of containing 2–3 days' supply. The damage done to machinery by the presence of stones has led to the introduction of "stoning-machines." The stoner invented by Collas, of Dixmude, and made by Lecointe et Villette, is shown in Figs. 1294–5. The tank *a* is divided into two compartments by partitions *b c*, forming between them a right angle, the vertical one *b* constituting a strainer at its upper part, and the horizontal one *c* occupying only about ⅔ of the length of the box, fixed at a certain distance above the bottom, and having a circular central orifice. Therein is placed a horizontal screw *d* with 4 arms, similar to those used in navigation. A horizontal grating is provided in the compartment *m* on the left, in prolongation of the horizontal partition on the right, and an inclined grating *e* in that (*n*) on the right, above the vertical partition. The apparatus being filled with water, and the screw set in motion by the bevel-wheels *f*, a circulatory movement is communicated to the water, which rises in the compartment *m*, passes above the strainer, and, traversing the inclined grating *e*, returns to the compartment *n*, and again comes under the influence of the screw. If beets are thrown into this rapid current in the compartment *m*, the stones rest on the grating or fall to the bottom, while the roots, by virtue of their relatively small sp. gr., are taken up by the current of water on to the inclined grating *e*, and tossed out of the machine by a little drum *g* armed with sloping flanges *h*, and driven by cog-wheels *i*. A trap-door *k* allows the vessel to be emptied of dirty water, and of the mud and stones which collect on the bottom. A vertical panel *l* of sheet iron, placed above the compartment *m*, prevents the beets falling directly on the inclined delivery-grating, and protects the driving-gear from splashings of water. The machine is already employed in several factories, being generally placed after the washer, and performing a second washing, which is especially valuable when the diffusion process is adopted.

The washer, Figs. 1296–7, consists of a perforated sheet-iron cylinder *a*, revolving on its axis in a tank of water *b*. In front of the tank, is bolted a hopper *c*, into which the beets fall; behind is a strainer. The cylinder leaves a space of only about ½ in. at each end of the tank, that the roots may not get wedged in. The washed roots are thrown out by a helical grating *d* placed at the end opposite to the hopper. The rounded bottom of the tank is inclined towards an opening, by which the dirt and rootlets can be discharged. Another form of washer, shown in Fig. 1298, is designed to overcome the disadvantage manifested by the preceding, in requiring frequent stoppages while the water is being changed. It consists of an archimedean screw working in a trough. The beets are fed in at *a*, and are carried by the screw against a descending stream of water in the direction indicated by the arrow, escaping at *b* perfectly clean.

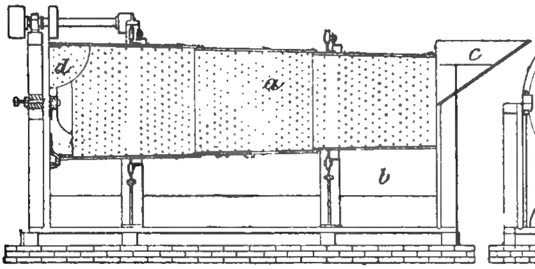
1294.



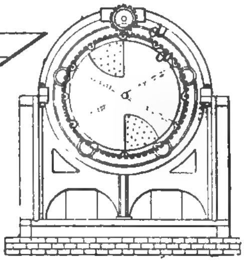
1295.



1296.



1297.

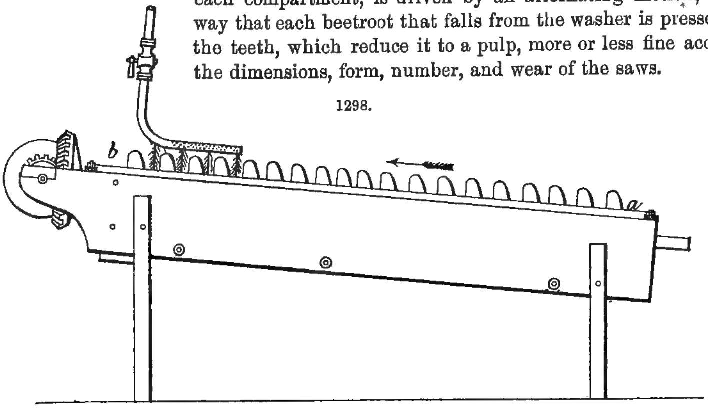


The processes described thus far are of universal application: the stoning and washing of the roots are needful preliminary operations, whatever mode of extracting the juice may be adopted. Here the parallel ends, and it is necessary to classify the succeeding methods of manipulation. They may be grouped under the following heads:—(*a*) Rasping and Pressing, (*b*) Maceration, (*c*) Diffusion.

Rasping and Pressing.—The principles which govern this process are essentially mechanical. The aim of the operations is to first comminute the root so as to effect the rupture of the greatest possible number of cells, and then to separate the liberated but still absorbed juice from the solid matters by means of pressure, whether of a press or of a centrifugal hydro-extractor.

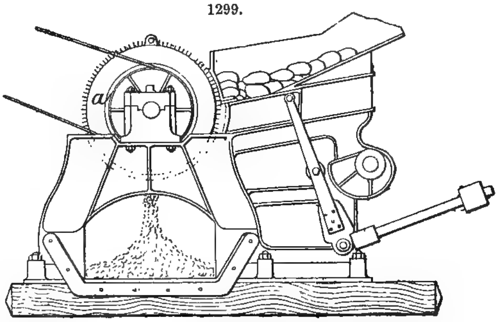
Raspers.—Machines for reducing beets to a pulp are of multitudinous forms, and it would be impracticable to describe all of them. They universally consist of a revolving drum armed with teeth, and differ mainly in having the dentition external in some cases and internal in others. The type of the first class is shown in Fig. 1299. The cylinder *a*, 24 in. diam., has its surface formed by a series of saw-blades (shown full-size in Fig. 1300), separated by wooden washers. The cylinder is divided into 2 or 3 compartments by intermediate false bottoms, and is driven at a speed of 800–1000 rev. a minute. It rotates in front of an inclined table, on which a pusher, placed before each compartment, is driven by an alternating motion, in such a way that each beetroot that falls from the washer is pressed against the teeth, which reduce it to a pulp, more or less fine according to the dimensions, form, number, and wear of the saws.

1298.



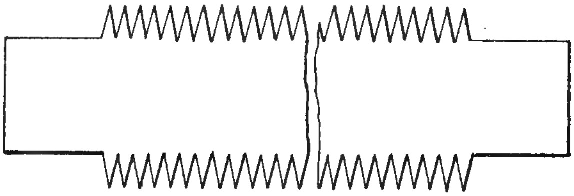
The typical representative of the internal system of grating is Champonnois' rasper, shown under Starch, p. 1824, Fig. 1284. The beets are introduced by the hopper *a*, and are forced by the rapid rotation of the fliers *b* (800–1000 rev. a minute) against the short saw-like teeth of the raspers *c*. Water is at the same time injected at *d*. Fast and loose pulleys are shown at *e f*, and a fly-wheel is fixed on the end of the shaft *g*. The machine is reversed every 6 hours to equalize the wear, still the saws require sharpening after 48 hours' use. The pulp falls into a receptacle beneath.

1299.



Presses.—The pulp obtained from the raspers is carried or pumped up from the cistern in which it has collected, to be submitted to expression. The presses used are of two kinds, alternating (including screw and hydraulic) and continuous. For the hydraulic press, the pulp is placed in woollen sacks, containing 10–12 lb., superposed in the press with their mouths doubled under, and separated by iron plates; about 25 are collected, and the pile is put into a screw-press, called a "preparatory" press, which extracts about 45–50 per cent. of the juice. These pressed sacks are piled anew on the movable plate of a powerful hydraulic press, which takes 50 at a charge. Each preparatory press can supply 4 hydraulic presses, which are ranged around it, so that of the 4 presses, there will be one charging, one commencing to press, one in full pressure, and one discharging, at the same moment. Motion is communicated to the 4 hydraulic presses by 4 pumps mounted on the same bed, and tended by the same workman who directs the pressing. An improvement upon the general form of hydraulic press is that devised by Lalouette, which enables 2 workmen and 1 boy to keep 5 presses at work. These presses turn out about 300 cwt. per 24 hours in the first pressing, and 600 in the second. Hydraulic presses are rapidly falling into disuse in the beet-sugar industry, by reason of the superior merits of continuous presses, and the extended adoption of the diffusion system.

1300.



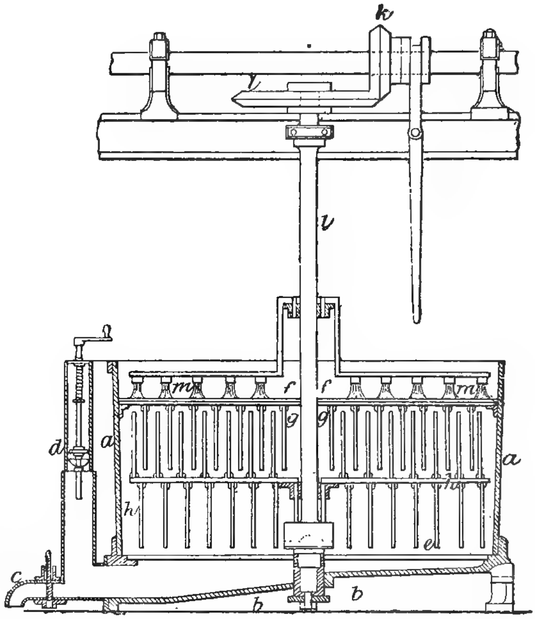
Continuous presses for beet were suggested by the roller-mills used in the cane-sugar industry. But the conditions in the two cases are widely different: the begass of the cane is solid, and readily parts from the juice; whereas the pulp and juice of the beet have a strong tendency to combine, and the roller-surface must therefore be permeable only by the juice. In Poizot et Druelle's press, the pulp passes between two cylinders, carried by endless cloths. The object is to unite the best features of the hydraulic press. To this end, a first gentle pressing is produced against the first cylinder by the elasticity of the principal cloth on which it is borne. Then, encountering a series of 4 little rollers, performing the functions of the preparatory press, it is next seized between the second and first cylinders, and deprived of the maximum quantity of juice. The press has been much improved since it first appeared. Manuel et Socin's press, made by Cail et Cie., has an ingenious modification by which the hair-cloth carrying the pulp is kept of a constant width. Each press, worked by one man, will treat the pulp of 1375–1570 cwt. of beet per diem, requiring scarcely 1 H.P. The juice, filtered through the hair-cloth, is free from pulp. The cost of manipulation is about 4*d.* per ton of root; the yield is 26–28 per cent. of pulp. The juice can only be perfectly extracted by a second pressing. To effect this, two first-pressure presses are used for one second-pressure. The pulp falls from the first into the trough of a screw, where it is mixed with a large quantity of water. Between the second and third presses, is another screw, which raises the softened pulp to the third press for a second pressing. The whole operation only occupies 25–30 seconds. The juice of the second pressing is used instead of water in the raspers, as the rapidity of the work prevents it undergoing any change, so that the juices are sent to the carbonization stage almost at the degree of density which they possessed while in the root, and the pulp retains but little sugar. Champonnois' press is composed of two permeable rollers partially immersed in a cast-iron tank, forming a watertight joint with their bases and with the portion emerging at the surface. The pulp can only escape between the rollers. A pump conveys the pulp leaving the raspers, and forces it into the tank under a pressure of 1–2 atmos. The juice passes out between the rollers, while the exhausted pulp is raked away by two knives, which seize it immediately at the exit, and falls by its own weight in front of the press, inclined for the purpose at 45°. The cylinders are driven in opposite directions. The filtering surface is formed by spiral windings of a triangular thread, the spaces being determined at 0·004–0·008 in. In this way, is produced a filter-surface having narrow openings on the outside and widening inwards. On leaving the press, the juice is received by a sieve, which prevents the loose pulp from mixing with the juice. The press has been further improved in the hands of Cail et Cie., and is now one of the most perfect and least costly in the market. Lebée's press is also composed of two filter-cylinders, in appearance somewhat resembling Champonnois', but essentially different in construction. It is formed of a series of portions of filtering surface, screwed on side by side, and enveloping the cylinder; each portion consists of 10 little strips of copper, curved longitudinally, soldered at the ends, and separated by intervals of 0·004–0·008 in. This press allows the filter-surface to be changed more easily than in the Champonnois press, without removing the cylinders; but it is not so simple. Cuvelier's press, constructed by Lobbedez, has been at work for some years at Louez, near Arras, and gives 28–30 per cent. of pulp retaining very little sugar. Piéron's system has been adopted at the Montigny factory: the preparatory press treats nearly 2000 tons of beetroot per 24 hours; the ordinary first press, nearly 800 tons; and the second press, over 1500 tons. Sufficient has now been said to illustrate the principles and essential features of continuous presses for separating the juice from the pulp of mashed beets. Examples might be multiplied almost indefinitely.

Depulpers.—The term "depulpers" has been applied to a class of apparatus rendered necessary by the inability of the ordinary filters to completely remove the fine pulpy matters from the juice. They are really nothing more than effective mechanical filters. That of Loynes, made by the Cie. de Fives-Lille, is largely used in other industries besides beet-sugar making. Those of Mariolles and Mesnard are constructed by Cail.

Centrifugals.—Centrifugal hydro-extracting machines, which are described under Cane-sugar and Refining, have been tried for separating beet-juice from the pulp of the grated roots. In practice, however, they are incapable of extracting more than 60–65 per cent. of the juice under the most favourable conditions, and consequently they are not superior to hydraulic presses. Their use in this sphere is virtually a thing of the past.

Maceration.—The shortcoming of the expression processes gave an impetus to experiment in other directions, and notably with regard to the dissolving and displacing powers of water when applied to the pulp. One of the earliest plans based upon these principles was the maceration system of Schutzenbach, illustrated in section in Fig. 1301. The essential parts consist of round sheet-iron vessels *a*, the bottom *b* of each being made sloping towards one side, where the liquid can be completely drawn off by taps *c*. If the tap *c* is closed, the liquid rises in the tube *d*, and flows thence by a lateral pipe into a second similar vessel placed at a lower level. Above the bottom *b*, is a false bottom *e*, furnished with a metallic strainer, which retains the solid pulp while the juice escapes. At the top, in *f*, is a second similar strainer, formed in two pieces, and easily removable. The vertical bars *g* suspended from *e* are for breaking up the pulp, and preventing its making a simple rotation, under the influence of the mechanical agitator *h*, attached to the axis *i*, and actuated by the bevel-wheels *k l*. The same axis carries cleaning-brushes *m*, which keep the orifices of the upper grating clear for the passage of air and water; and a similar set perform the same function for the lower strainer. In working, each vessel receives at first a little juice (except at starting, when the juice is replaced by water); the pulp is then introduced, the agitator being meantime kept in motion, or the densest pulp would fall to the bottom, and soon choke the strainer. The speed of the agitator must be carefully regulated: too rapid movement would create a large quantity of froth; too slow would reduce the rapidity of the maceration, and therefore the effective capacity of the apparatus. A speed of 20–24 turns a minute would seem to give the best results. Later, when the juice is partly expressed, the agitator may be left at rest; the ligneous portion of the cells, being lighter than the water, remains on the surface, and has no longer a tendency to choke the metallic diaphragm.

1301.

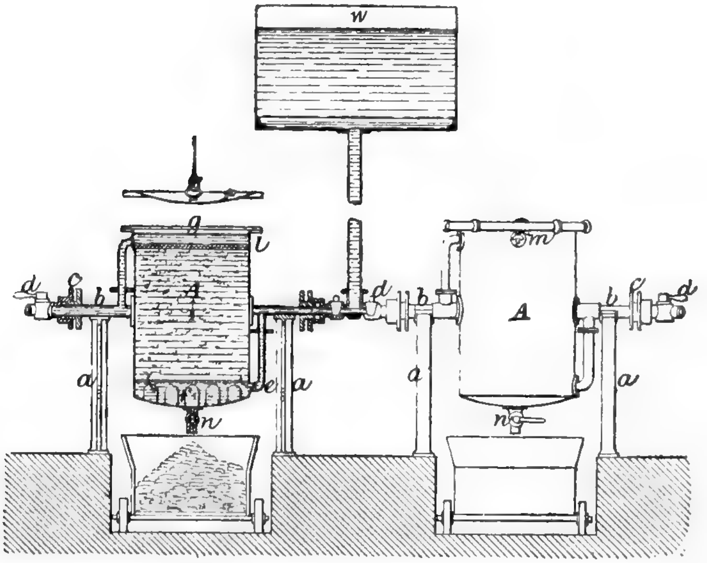


Unfortunately, whatever precautions are taken, a large proportion of pulp always finds its way through the strainer, and these solid matters render the defecation more difficult and imperfect, in consequence of the large quantities of scum to which they give rise. This inconvenience is partially remedied by passing the juice, on its exit from the maceration battery, and before defecation, into another vessel, whose strainers serve to detain some of the ligneous matters held by the juice. With the same object, it is well not to reduce the root to too fine a pulp; but it is necessary to avoid extremes in either direction, as a too coarse pulp will not be completely exhausted, and will thus cause a loss of sugar. The process is only suitable for use where fuel is abundant and cheap, in consequence of the very large quantity of water added, amounting in all to 3–4 times the weight of the root. It is therefore more applicable to rich than to poor juice. The cost of erection is moderate. Thus, for a factory taking 50 tons daily, the outlay would be:—Rasping-machine, 180*l.*; macerating-battery complete, 600*l.*; press, 200*l.*; steam-engine, 8 H.P., 200*l.*; total, 1180*l.* The expenses attending the extraction of the juice would be:—6000 tons of beet at 19*s.*, 5700*l.*; transport and washing, 160*l.*; interest at 10 per cent., 180*l.*; repairs, strainers, brushes, &c., 120*l.*; wages of 24 workmen, 134*l.*; washing the cloths, &c., 14*l.*; fuel for the steam-engine, 105 tons of coal, 150*l.*; fuel to evaporate 35 per cent. of water, 420 tons coal, 605*l.*; total, 7063*l.* The yield is 89 per cent. of juice, or 5034 tons in the season. The cost price is therefore 31*s.* a ton.

L. Walkhoff's "mixed method" of extraction is illustrated in Fig. 1302. Its most essential part is the filter-press or swinging vat A, resting by the axles *b* on cast-iron supports *a*; it can be turned round on its axis, and thus completely emptied. One or both of the axles *b* are hollow, and furnished with a stuffing-box, so that water can circulate in the interior of the axles, whatever the position of the vessel. A tap *d* regulates the delivery of water from a reservoir *w*, which may be 10–30 ft. above the apparatus. The water admitted by the hollow axles *b* passes by the pipe *e* into a perforated worm, whence it escapes beneath the double false bottom *f*. Thus its level is raised slowly and uniformly. At *g*, is a cover pierced with holes, forming a diaphragm, provided with a handle, and resting in the interior of the vessel upon circular bearers, where it is held by screws. To prevent the water passing directly along the sides, the double false bottom is fixed to a T-iron rim riveted to the vessel. The large-bore tap *n* is for letting out the water rapidly when the juice is displaced. At the top of A, is a tap *m* for outflow of juice.

Once the vessels A are full, the metallic strainer *l* is placed on the pulp, and the cover *g* is adjusted. The tap *d* is then opened, so that the water occupies 12–20 minutes in filling the vessel A. The water enters at the bottom; as it rises, it displaces the juice in the pulp, mixing more or less with it. The liquid thus approaches the tap *m*, and escapes at about the normal density of the juice. The workman soon learns the correct adjustment of the tap *d* necessary to give the proper duration to the operation. The pulp, being lighter than the water, rises as a scum up to the strainer *l*, but is there retained, so that the liquid escapes quite clear. The usual length of operation required is 20 minutes. The diameter of the vessels A should not exceed about 28 in. With this size, the pulp of about 8 tons of beet can be worked in a day of 24 hours, or say 6 vessels for 50 tons per diem. This system has been very largely adopted in continental Europe, on account of its good working results. The appended table exhibits its capabilities in comparison with other modes:—

1302



	Yield of Juice.	Yield of Pulp at uniform dryness.
	per cent.	per cent.
Ordinary presses	80	20
Simple presses, with 50 to 60 per cent. of water added in the rasper	84	16
Kuhne and Bökelmann's double pressing	87	13
Schlickeysen's process	88½	11½
Walkhoff's "mixed method"	92	8

More recently, Walkhoff has introduced modifications tending to reduce the labour. His principle is to reduce about 70–80 per cent. of the juice by a preliminary treatment, of the simplest possible character, for which many mechanical appliances already exist. The pulp coming from this treatment is thrown at *a* into the apparatus shown in Fig. 1303. Thence it passes under a great number of blades, which divide it into small fragments, and thus it reaches the large drum *b* in a uniform and continuous stream, there to be still further comminuted by the edges *c*, and delivered to the juice-extractor. This latter, called a "revolving filter," is provided with paddles, and resembles a water-wheel. This revolves slowly, and causes the pulp to circulate in opposition to a current of water entering at *e*. The completely exhausted pulp is discharged at *g*, and falls into the gutter *h*, whence it is conveyed to store. The whole apparatus rests by its axis *n* on a support *m*, and is actuated by the wheels and pulley shown. The tap *o* serves as an outlet for the water from the apparatus. The water, entering in the desired quantity at *e*, passes successively into each compartment, and escapes at *f* as concentrated juice. The apparatus is very simple, and effects the complete extraction of the sugar, without adding more than 5 per cent. of water on the weight of beetroot.

Many other plans, depending more or less upon maceration, have been proposed, such as Pelletan's, Reichenbach's, Hallette et Boucherie's, Martin et Champonnois', Schiskoff's, Robert's, Schutzenbach's, &c., but they do not possess any valuable feature entitling them to notice. The preceding systems are those most generally and successfully applied. A comparison of the results of the foregoing processes, in tabular form, is given on the authority of Walkhoff: for 120 days' work and 6000 tons of beet, the production of juice requires:—

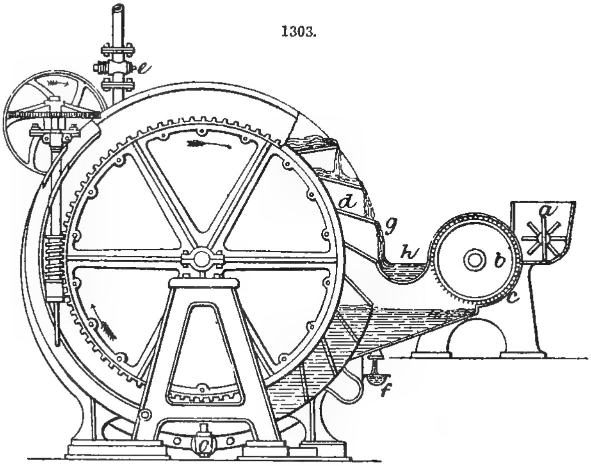
Processes.	In Labour:			In Fuel:		Cost of First Establishment.	Annual Expenses for Repairs.	Percentage of Juice obtained.	Cost of Production per Ton of Juice at the Initial Density.		Percentage of Water added to the Juice.
	For Collecting and Cleaning the Beet.	From the Rasping to the Defecation.		For the Engines.	For Evaporating the added Water.						
		Per Shift.	Total No. of Days.	In tons of English Coal.							
						£	£		s.	d.	
Simple expression	3360	28	6720*	118·8	..	1340	288	80	28	0	..
Expression with second rasping of the pulp ..	3360	35	8400*	145·2	240	1540	300	87	27	9	20
Expression with the charging-tables adopted at Smela in 1862 ..	3360	14	3360*	118·8	..	1200	288	80	27	6	..
Centrifugals	3360	10	2400	237·6	360	1450	120	88	27	0	30
Schutzenbach's maceration	3360	12	2880	105·6	420	1140	120	89	31	0	35
Walkhoff's method ..	3360	20	4800*	130·2	125	540†	272	89‡	36	0	8–12

* Not including the washing of the sacks. † Plus the presses.

‡ This method gives up to 94 per cent. of juice, and the figure stated is the absolute minimum.

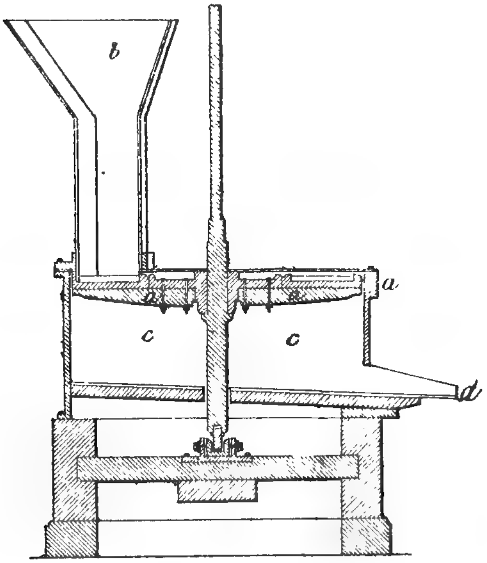
Diffusion.—The processes hitherto described for extracting the juice from the beet have depended for success upon the more or less complete rupture of the cells containing the juice. "Diffusion" differs from them essentially, in dispensing with the breaking-up of the cells. The constituents of beet-juice may be classed under two distinct groups: (*a*) "crystalloid," including the sugar and other "salts" capable of assuming a crystalline form; (*b*) "colloid" (glue-like), embracing the gummy or mucilaginous matters not capable of crystallization. The two classes are distinguished by a physical fact which forms the basis of all modifications of the diffusion system,—the difference which they manifest with regard to the power of passing through moist water-tight membranes. Bodies belonging to series (*a*), dissolved in water, pass through most animal and vegetable membranes (gut, parchment, plant-cells, parchment-paper), when there is water on the other side; those of series (*b*) are not possessed of that property. This method of separation is termed "dialysis," "osmosis," or "diffusion," and the membrane is called a "septum" or "dialyzer." The dead cell-walls of the plant itself form an excellent dialyzer; therefore, by cutting the root into convenient slices, and soaking these in water, the crystalloids (including the sugar) pass through the cells into the surrounding water, while the colloids mostly remain in the cells. Thus the juice is at once more or less purified, and is at the same time less contaminated with vegetable débris resulting from the mechanical breaking-up of the root.

1303.

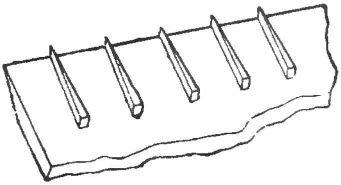


If slices of beet are placed in a vessel with about the same quantity of water, the following changes take place. The water forces its way through the cellular membranes into the sugar-cells, displacing a portion of the saccharine solution, which passes out, thereby diminishing the sp. gr. of the juice left in the cells, and increasing that of the water outside; this interchange continues till the liquid in the vessel has attained the same sp. gr. as that in the cells: the diffusion is then complete. Supposing the juice in the cells to be at sp. gr. 1·0435 (equal to 12 per cent. by saccharometer), and the surrounding water 1·0000, when the diffusion is complete, the water will be sp. gr. 1·0237 (equal to 6 per cent. by saccharometer), and the now diluted juice in the cells the same. Consequently complete exhaustion can only be accomplished by fractional diffusion, i. e. by substituting for the liquid obtained another of less sp. gr., and this replacing of the more saturated liquid by a less saturated one must be continued until the desired degree of exhaustion is reached.

1304.

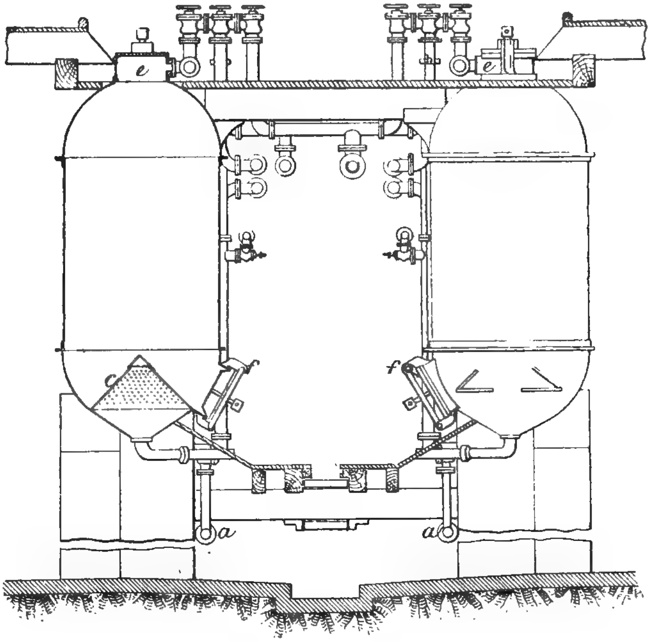


1305.

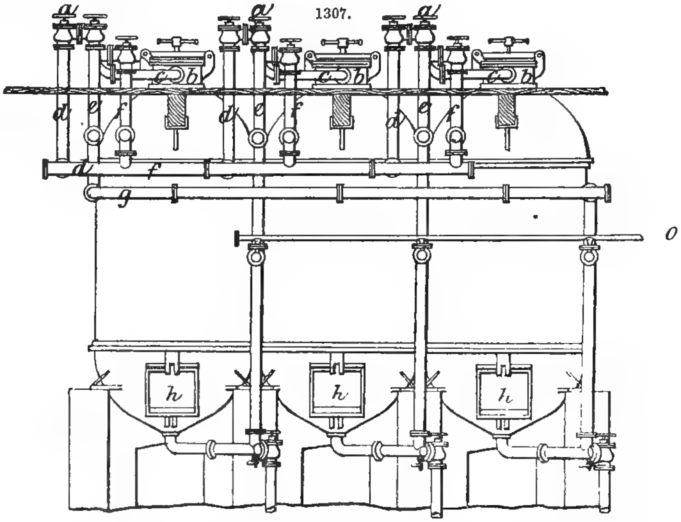


The first step in the process is to cut the roots into thin slices, great importance attaching to their thickness being uniform. The machine in common use, invented in 1850 for slicing beets for the hot maceration process, is shown in Fig. 1304. The cleaned roots fall into the hopper *b*, and encounter a plate *a* which turns horizontally, and carries 3 series of steel blades arranged at right angles. The roots are thus divided into rectangular prisms of varying length, without suffering any crushing or pressure. The slices fall into the space *c*, and escape at *d*. With 1½ H.P., this machine is said to slice 100 tons of beet per 24 hours. By using two feed-hoppers, the effect is doubled. For diffusion, the slices are about $\frac{4}{100}$ in. thick and $\frac{40}{100}$ in. wide. The cutting disc is furnished with knife-edges, as shown in Fig. 1305.

1306.



In Robert's diffusion process, the ribbon-like slices of beet are conducted to large closed vessels, mixed with the heated juice from a previous operation, and exhausted with cold water. The diluted juice is first heated to 75°–90° (167°–194° F.), so that the mixture assumes a mean temperature of 50° (122° F.), which is considered essential to success. Displacement of the juice is performed by a flow of cold water throughout the whole battery (of 5 to 8 vessels), arranged as in Figs. 1306 and 1307. The cylinders are furnished at top with manholes *c* for the introduction of the slices. Near the bottom, a hinged door *f* permits the exhausted slices to fall upon an endless web, which conveys them away. In the interior of the cylinder, is a case *c* pierced with holes, which prevents the pipes being obstructed by solid particles. The pipes *a e* put the vessels into communication with the reheating boilers, while the conduits *e g* and *c* maintain the circulation in the various cylinders of the battery. The steam-pipe *o* furnished with a clack serves for the introduction of steam to the several vessels. Pipes *d* bring the water necessary to the operation, while the rich liquor passes away by *f* to the defecating-boilers.

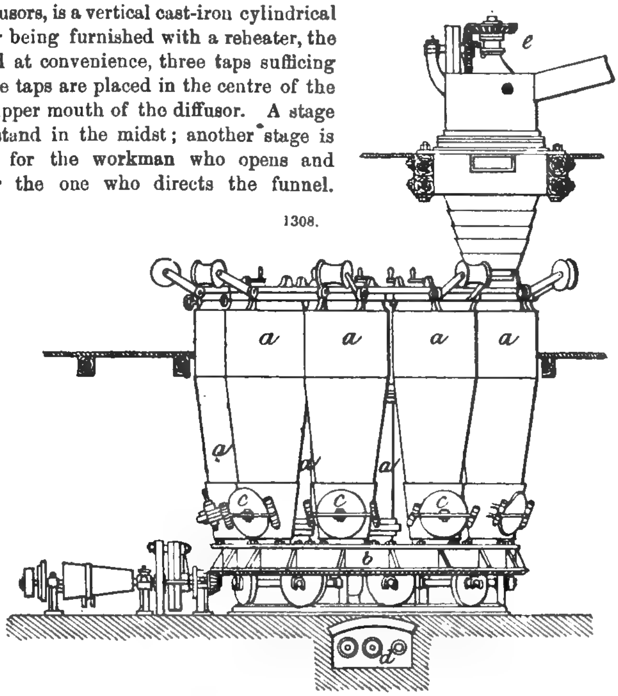


1307.

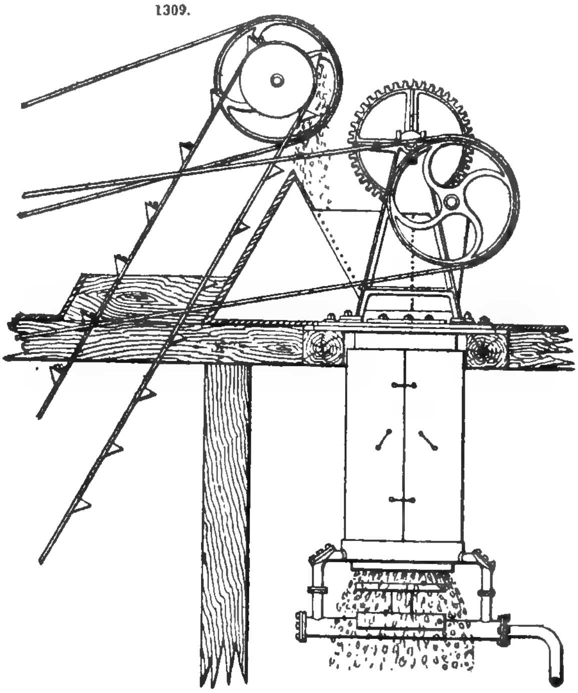
Each vessel receives 2½ tons of slices, occupying a space of about 132 cub. ft. The vessels are not filled until the juice or the diffusion-water, as the case may be, has a temperature of 87°–97° (189° - 207° F.). The vessel is ⅓ filled with this hot liquid, and then the slices are fed in through *e* from trucks holding about ½ ton. On emptying the fourth truck, the reheated juice is allowed to run in at top, so that when the charging of the slices is completed, the vessel is full of juice. The proportions of juice and pulp entering the vessel should be carefully adjusted. Whilst charging, it is well to mix up the juice and pulp so that no part shall be left imperfectly exhausted, and the liquids shall have uniform circulation. As the contents of 6 or 7 trucks are needed to fill the vessel, and as the discharging of each occupies about 4 minutes, the whole charging requires nearly half an hour. The vessel once full, the cover *e* is closed, and the matters are left for about 20 minutes. At this moment, the pressure of the column of water from the tanks above the factory is brought to bear upon the nearly exhausted pulp in the last vessel. As this vessel communicates with the 7 others forming the battery, the pressure can be conveyed to them all; the juice is thus displaced from the cylinder filled with fresh pulp, and proceeds while still hot to the defecating-boilers. In practice, each vessel furnishes two full boilers of juice, varying in density according to the duration and the number of vessels (5, 7, and even 10). Generally, the density fluctuates between 4° and 7° B., so that the juice is mixed with about 40 per cent. of water on the weight of beet.

The estimated cost of establishing a factory on the diffusion system to work 50 tons a day, according to Walkhoff, is:—1 slicing-machine, 144*l.*; 10 cast-iron diffusors, weighing 1 ton each, 288*l.*; 50 cast-iron valves, 180*l.*; 20 traps, 52*l.*; 30 elbow-pipes, 13*l.*; 15 straight pipes, 22*l.*; 600 screws, &c., 14*l.*; 3 trucks, weighing 6 cwt., 50*l.*; total, 763*l.* The cost of extracting 100 parts of juice may be calculated thus;—6000 tons of beetroot, 5760*l.*; transport and cleaning, 161*l.*; interest and insurance at 10 per cent., 76*l.*; 15 workmen per shift, or 30 per diem, 173*l.*; removal of the residues (60 to 70 per cent. of the weight of beet), 4 workmen, 46*l.*; repairs, sharpening knives, &c., 58*l.*; residue-press, interest, repairs, &c., 50*l.*; fuel for 8-H.P. steam-engine, 88 tons of coal, 127*l.*; evaporation of 40 per cent. of water, requiring 480 tons of coal, 691*l.*; total, 7142*l.* The product is 90 per cent. of juice at the initial density, or, on 6000 tons of root, 5400 tons of juice. The juice, therefore, costs about 26*s.* 5½*d.* a ton; thus diffusion presents no advantage in this respect over the best systems of maceration.

A novel arrangement of diffusion apparatus, constructed by the Prager Maschinenbau Co., is shown in Fig. 1308. It is designed to take a maximum of 250 tons of beet per diem of 24 hours. This quantity is worked in Bohemia, where the juices are very dilute; if, instead of having juice at 3° B., it is desired to have it at 4° B., not more than 100 tons would be treated, at a sugar loss of 0·2 per cent. on the pulp. Four workmen suffice for the daily labour. In effect, the apparatus is rotary. The 9 diffusors *a* of which it is composed, having the form of inverted truncated cones, are borne in a circle on a wheeled table *b*. The motive power giving the rotation is ingeniously applied, and does not exceed 1 H.P. A complete turn is made in ¾ hour. The slicing-machine (*coupe-racines*) *e* is placed above on a special stage, and supplies the slices to each diffusor by means of an articulated funnel, formed of movable segments, so that its mouth can follow the slow rotary movements of the diffusor which it is filling, until the quantity suffices. The axis of rotation of the apparatus is composed of two concentric cast-iron conduits, one conveying the water, the other the steam. Between each two diffusors, is a vertical cast-iron cylindrical juice-reheater. Each diffusor being furnished with a reheater, the temperature can be regulated at convenience, three taps sufficing for each apparatus. All these taps are placed in the centre of the system, at the height of the upper mouth of the diffusor. A stage fixed here allows a man to stand in the midst; another stage is placed at the same height for the workman who opens and shuts the diffusors, and for the one who directs the funnel. The diffusors are closed at top by a heavy cover, resting upon a circular india-rubber tube, thus forming a hermetic joint, steam being admitted into the tube, so that it never flattens. The outlet of the diffusors is a lateral door *c* opening from above; a trough is provided for the reception of the exhausted slices. The juice is let out by taps *d* below the ground. A perforated sheet-iron plate forming a false bottom prevents the slices from mingling with the juice, when the tap is opened and the outlet-vessel is completely emptied of slices. A workman opens the lower doors each time a diffusor passes before the trough for the slices. A fourth workman is occupied at the slicing-machines. The advantages claimed for this system are as follows:—Easy charging of the diffusors, the slices passing direct from the slicing-machines, whence arises great economy of labour; the discharge of the exhausted slices takes place always at the same point; the duration of the diffusion, being regulated by the speed given to the apparatus, is always the same, and not at the discretion of the workmen; there is great saving in the construction, the pipe system being central and necessarily short.



1308.



1309.

Numerous other modifications are being from time to time introduced. For instance, compressed air is employed instead of water-pressure for effecting the final exit of the juice, so that the first diffusor, at the moment of emptying, contains only fairly dry slices.

The exhausted slices derived from the diffusors form a valuable cattle-food. But, as generally discharged, they are too wet for immediate use, and require to be passed through a press for the removal of the excess moisture. This is commonly performed in the Kluzemann press, shown in Fig. 1309. It is composed of a screw working in a conical space, which squeezes the pulp till it contains no more than the desirable quantity of water. The objection to this press is that it breaks up the slices. Skoda, of Pilsen, Bohemia, makes a continuous press, which avoids this disintegration of the exhausted slices. It consists of two eccentric cylinders placed one within the other, of different diameters, moving in the same direction and at the same peripheric speed. A screw causes the wet slices to fall into the interior of the larger cylinder, and they are carried by the general movement into the limited space between the outer surface of the small cylinder and the inner surface of the large one, and which is regulated by a double iron ring fixed on the inside of the large cylinder. This machine easily presses in the 24 hours the exhausted slices from 150–175 tons of beet, reduced to 40–45 per cent. of the original weight. The motive power required is about 1½–2 H.P. The price of the machine is about 280*l.*

Defecation of the Juice.—The average composition of freshly-extracted beet-juice is approximately as follows:—

In 100 parts of juice.

Sugar.	Diffusion.			Sugar.	Expression.		
	Potash, Soda, Silica, Lime, and Magnesia.	Organic Substances.	Weight of Solid Matters.		Potash, Soda, Silica, Lime, and Magnesia.	Organic Substances.	Weight of Solid Matters.
9·138	0·507	1·288	11·65	11·25	0·671	1·467	15·658
In 100 parts of dry substances.							
62·203	4·958	13·565	19·274	59·419	4·952	14·973	20·656

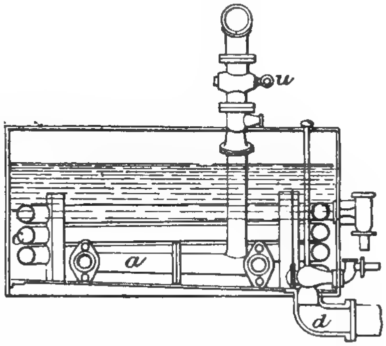
Defecation by Lime and Carbonic Acid.—This impure juice can be clarified to some extent by simple boiling, as the albuminous (nitrogenous) constituents coagulate in the same way as those of cane-juice, and form a supernatant scum; but the coagulation is very imperfect. The addition of slaked lime greatly facilitates the aggregation of impurities, by the formation of insoluble lime compounds; but a coincident effect is the prevention of the coagulation of the albuminous matters, which remain in solution till partially destroyed by boiling in the presence of the alkali. The part played by the lime is very complex, and not clearly made out, but it seems to displace many of the bases in combination with sulphuric, oxalic, and other acids, forming insoluble compounds with those acids, and further destroys some of the albuminous matters, as evidenced by the disengagement of ammonia when the temperature is raised. The convenience and cheapness of lime as a defecator are obvious. Its use underwent many modifications till 1849, when carbonic acid was proposed for neutralizing the excess of lime. In this direction, successive steps were made by Rousseau, Maumené, Périer et Possoz, Cail, Frey, and Jenileck, and the process, termed "double carbonation" (*double carbonatation*), has come into almost universal use.

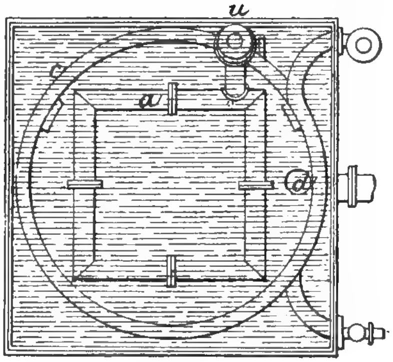
The method of carrying it into practice is as follows:—(1) Put lime into the juice as soon as possible, even into the mixture of juice and pulp, by introducing milk of lime into the rasper, or a weak solution of sucrate of lime, which, under proper conditions, does not appreciably alter the value of the pulp as a cattle-food. (2) Let the contact of lime and juice be sufficiently long, such as when preserving juice in cisterns, in the store-tanks at the exit from the rasping, or when transmitting it through the Linard pipe system (p. 1836); thus the free acids which would alter the sugar are saturated, and a very satisfactory cold defecation is obtained. (3) Introduce the turbid juices into the first-carbonation vessels, described further on, then adding $\frac{15}{1000}$ to $\frac{30}{1000}$ of lime in the state of milk of lime. (4) Pass carbonic acid gas in the cold up to about the middle of the carbonation; then gently admit steam to warm the juice; the supply of carbonic acid is stopped when the juice does not contain more than $\frac{2}{1000}$ of lime. (5) Turn the steam on full till the temperature reaches 90° (194° F.), to throw up the scum; allow to rest, and decant. (6) Transfer the clear juice to the second-carbonation boilers, add $\frac{2}{1000}$ to $\frac{10}{1000}$ of lime, and heat to boiling, in order to destroy the nitrogenous matters not eliminated by the first carbonation. (7) Pass carbonic acid till the lime is completely saturated. (8) Give a rapid boiling, allow to settle, and decant.

In the double carbonation process, the purification is effected in two ways. The carbonic acid, in uniting with the lime in the midst of the juice, forms carbonate of lime, which, on precipitating, carries with it a large quantity of organic matters. The scums of the first carbonation are thus very dark. The supply of carbonic acid is stopped when its further action would redissolve the colouring matters. In the second carbonation, the lime-boiling destroys the matters which resist the first carbonation. The excess of lime is finally removed by carbonic acid.

The apparatus and its manipulation may be described as follows. At the exit from the presses and the diffusors, the juice is received either directly into the carbonation-boilers, or into a tank communicating with a pump or *monte-jus*, for filling the carbonators placed at a higher level. The *monte-jus*, pumps, and defecating- and clarifying-boilers will be found described under the section on Cane-sugar. The carbonating-boilers are of various forms, composed essentially of large rectangular tanks (Figs. 1310, 1311), generally of greater depth than width. Around their circumference, passes a steam-worm *c* of large diameter, to rapidly heat the mass of liquor. At the bottom of the tank, runs a pipe *a*, which separates into two branches, or takes the form of the tank. This pipe is pierced beneath with small holes, whose total area is less than the section of the pipe; at the end, it rises in front of the boiler, and bears a tap *u* within the operator's reach. It then conducts to the carbonic acid source, and serves for introducing this gas into the liquor. The bottom of the boiler is inclined towards the front, and has in the lowest part a large plug *d*, or a tap for rapidly drawing off the liquid. Thermometers are attached for ascertaining the temperature. The boilers are the same for the first and second carbonation, except that the first produces a tenacious scum which must be beaten down. This is effected in two ways: either by furnishing the boilers with ledges, and a cover provided with a long chimney, when the scum stops at a small height in this pipe; or by placing at the top of the boiler, throughout its whole length, perpendicularly to the side where the workman stands, and on each side, two pipes of small diameter pierced laterally with little holes, through which steam is passed at high pressure. The escaping steam blows the scum back into the boiler. This latter apparatus, termed "Evrard's skimmer," works well, but requires much steam.

1310.





1311.

Below each carbonating-tank, is placed a decantation-vessel, generally of the same form and dimensions, into which the liquid flows when let out of the carbonators by the plug. These decantation-vessels, whose floor is also inclined and furnished with a plug, have in front an external tap, connected inwardly with a flexible tube provided with a float which maintains the mouth of the tube at the clear surface of the liquor. When the turbid carbonated juice has been run into these vessels, it is allowed to settle and clarify itself, and is then decanted. The clear juice is received in a conduit which conveys it to the second carbonation, or to the filtration. When the float reaches the deposit, the workman closes the tap, opens the plug, and lets out the semi-solid mass into a trough connected with the filter-presses (p. 1848). In some works, the decantation-vessels are dispensed with, the operations being conducted in the carbonator.

The lime and carbonic acid employed in the operations are usually made at the factory. With this object, a large continuous lime-kiln, Fig. 1312, is built near. The gases escaping from the calcination of the limestone contain 25–30 per cent. of carbonic acid gas; they are drawn away from the exit of the kiln by the suction of a large pump, whose speed is regulated according to the state of the kiln. This pump forces the gas into the general pipe serving all the carbonators, which pipe is furnished with a safety-valve. Between the kiln and the pump, the gas traverses a "washer," a vertical cylinder with perforated trays, entering at the bottom by a perforated pipe, and escaping at the top by the pipe *f*, while a stream of water, conveyed by the pipe *p*, falls in showers over the trays and comes into contact with the ascending gas. According to the richness of the gas, the kiln is regulated: it is thus necessary to make frequent tests of the gas. One of the most convenient instruments for this purpose is that of Wigner and Harland. The lime to be used in defecating is first slaked in special tanks furnished with agitators. It is then diluted with sufficient water, carefully strained, and constitutes a milk of lime having a density of 20°–25° B.

Treatment of the Lime Scums.—The scums collected in the lime defecation process contain, in the fresh state, sugar, numerous nitrogenous matters, and other fertilizing elements. Plicque, working upon scums having the composition:

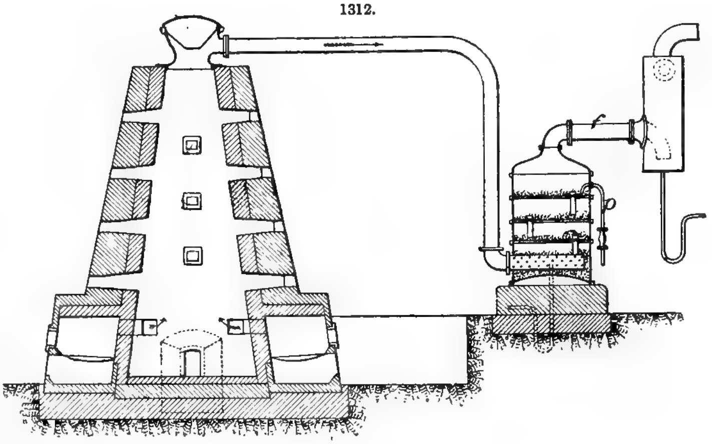
Water	52·70 per cent.	Organic matter	9·24 per cent.
Sugar	3·50 „	Phosphates	4·77 „
Nitrogenous matter	3·72 „	Lime, silica, iron, &c.	26·07 „

obtained the following products, estimated on the dry weight:—

Animal black	50·0 per cent.	Alcohol at 85°	2·0 per cent.
Lime	35·5 „	Sulphate of ammonia	1·0–2·0 „

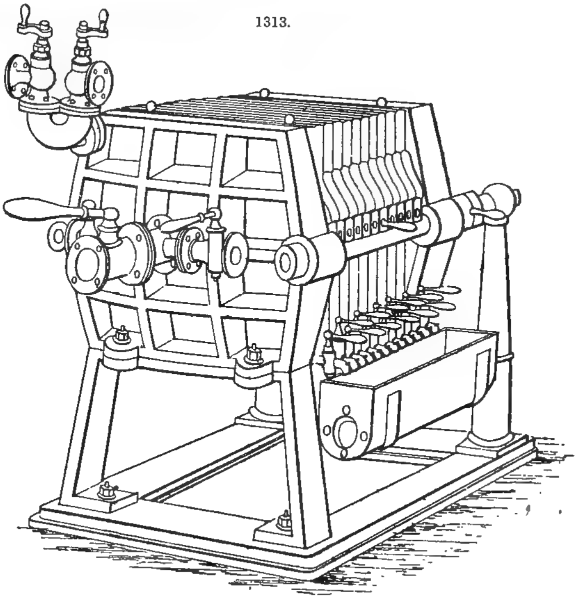
The excess of moisture is removed from the "green" scums by the use of filter-presses. The scums of the two carbonations are collected in the same cistern, fitted with two *monte-jus*. The escape-pipes from these *monte-jus* reunite into one, so that though the *monte-jus* are used alternately, there is no fluctuation in the supply of scum to the filter-presses. The systems most largely used are those of Trinks, and Durieux et Roettger.

1312.



Trinks' press, Fig. 1313, is composed of a series of cloth bags, held against metallic plates pierced with holes. The *monte-jus* forces the dirty liquid into these bags; the juice runs away clear, while each bag fills with the solid scum, which is strongly compressed by the steam in the *monte-jus*. When the bags are full, the juice no longer escapes; then, to remove the superfluous moisture from the scum, steam alone is forced in. The steam condenses and washes the scum, dissolving the last traces of sugar, and yielding a slightly saccharine liquor. The action of the steam is continued until, having forced a passage, it escapes at the lower part of the apparatus. Steam is then shut off, and the operation is concluded. To enable the bags to be opened easily, they are formed of two quadrangular cloths put together, the four borders of which are pinched, two and two, between wrought- or cast-iron frames, presenting an opening only for the passage of the scum and steam. The frame, and consequently the set of cloths forming bags, are separated by metallic plates, which permit the juices to escape; these juices run along the plates, and collect in a gutter closed by a tap, with screws to regulate the speed of the outlet, and even to suspend the working of a cloth, when it is torn for instance, without stopping the whole press.

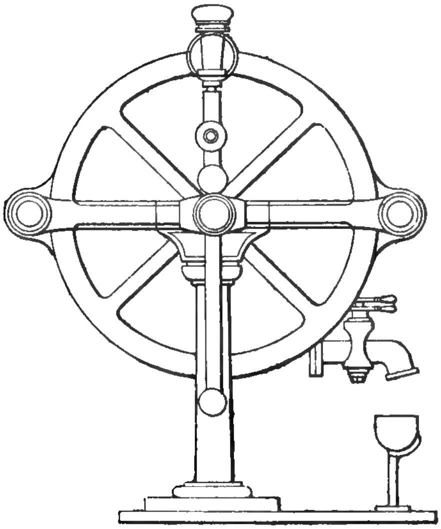
1313.

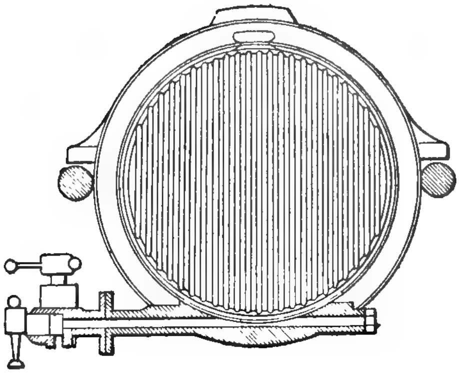


Farinaux's press is composed of plates analogous to those of Trinks. In the upper part of the frames are two bearers, on which is screwed a wrought-iron stirrup. A horizontal traverse is fastened to one side of the fixed frame, and passes through all the stirrups, supporting the frames. The advantages claimed for it are that it is easy to adjust all the frames to the same height, and that the dismounting and replacing of the frames is much easier. According to another plan of Farinaux's, the working of the press is rendered largely mechanical, so that one labourer out of two is dispensed with. The bags are made of sail-cloth, and last 24–30 days, while those of jute endure only 5–8 days.

Durieux et Roettger's press is shown in Figs. 1314 and 1315. Numerous other forms might be specified, but their effect is practically the same.

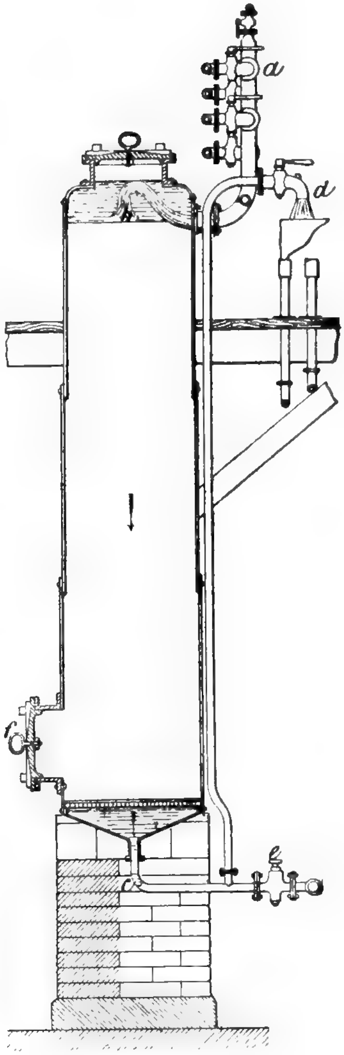
1314.





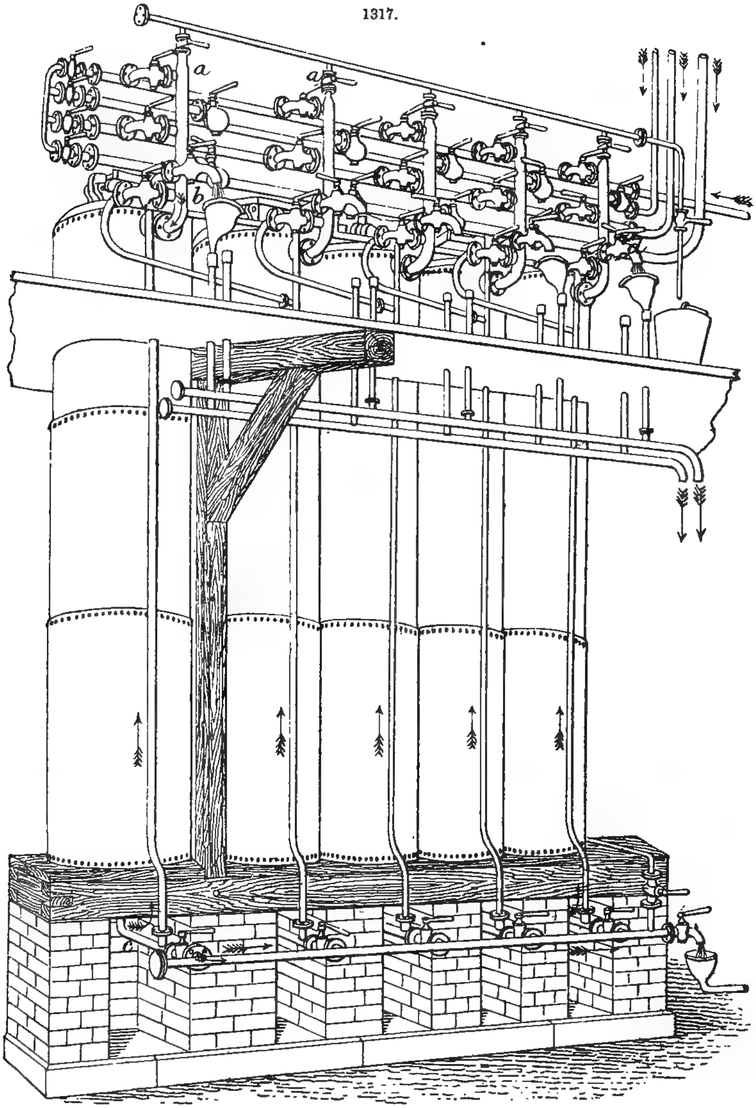
1315.

1316.



Ammonium phosphate Process.—A process was invented some years ago by Lagrange, chemist at the refinery of Guions, Paris, for separating the calcium and magnesium salts, with which beet-sugar is especially liable to be contaminated (see analyses p. 1846). The object of the process is to throw down the calcium and magnesium as tribasic phosphates, by the addition of tribasic ammonium phosphate, $(NH_4)\,3PO_4$, to the syrup. Much, sometimes nearly the whole, of these earthy salts, exists as sulphates, though portions are usually chlorides or nitrates. The salts of the earthy bases retard the crystallization of the sugar, with varying effect according to the particular metals they may contain; and the acids, especially if they be mineral acids, with which the earthy metals are in combination, likewise possess specific powers of their own in retarding the crystallization of more or less sugar. Sulphuric acid would appear to be the most powerful, while phosphoric acid seems to exert little if any influence; small quantities of ammonium phosphate are indeed stated to rather favour crystallization. Lagrange's process simply and ingeniously contrives to get rid of the calcium and magnesium, and, by the same operation, to precipitate and extract any sulphuric acid present.

1317.

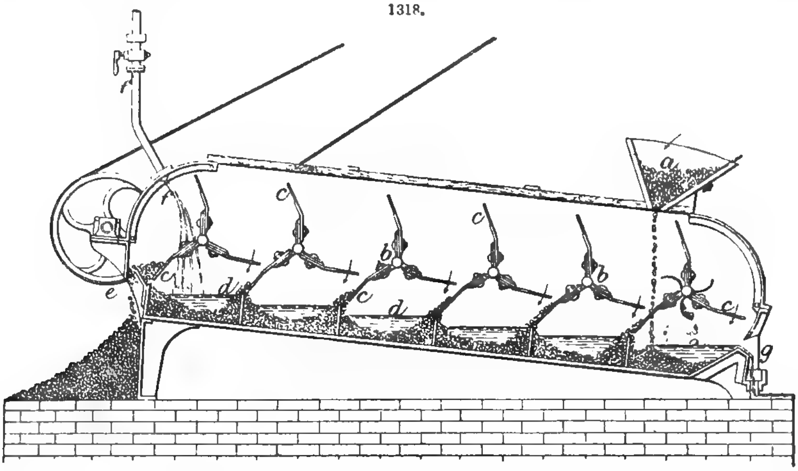


A quantity of syrup having been made, the amount of sulphuric acid and earthy salts present is ascertained, the latter by means of the soap test (see Analysis). It is now heated to boiling, and a solution of barium hydrate in hot water is added in trifling excess beyond what is required to combine with and throw down all the sulphuric acid; this is immediately followed by an addition of ammonium triphosphate, equivalent to or slightly in excess of the total earthy metals. These will consist of any excess of barium hydrate that may have been added, together with any calcium or magnesium originally present. A mixture of barium sulphate, barium triphosphate, and calcium and magnesium triphosphates, goes down, sweeping with it from the syrup much of the glutinous and colouring matters. The syrup is next passed through a Taylor filter, to separate the precipitate; if the operation has been properly conducted, the syrup should contain some free ammonia, and just a trifling excess of the ammonium triphosphate, but no earthy bases nor sulphuric acid. The syrup is now fit to be boiled and crystallized.

For some time after this process had been devised by Lagrange, it was impossible to procure ammonium triphosphate at reasonable prices, the only mode of manufacture being the production (1) of neutral ammonium phosphate, by saturating pure syrupy phosphoric acid with ammonia, so as to form a highly saturated solution of the salt, and (2) then adding one more equivalent of ammonia, so as to throw down ammonium triphosphate, which latter salt is only soluble in weak aqueous ammonia to the extent of about 6 per cent. F. Maxwell-Lyte, however, introduced a method of producing pure ammonium triphosphate from the acid calcium phosphate afforded by natural phosphates, which at once reduced the price of ammonium triphosphate from 2*s.* 6*d.* to 8*d.* a lb., and thus placed the salt within easy reach of the sugar-makers. Gnions, who employed the process in their refinery, state that, besides affording an additional 5–10 per cent. of crystallized sugar, they are enabled to work with far less animal-black (char). The process is equally adapted to the defecation of raw beet-syrups, and was thus worked for some time by Daniel, near Compiègne.

Filtration through Animal-black.—The defecated and carbonated juice has in a great measure lost its alkaline character, having been deprived of the greater part of the dissolved lime by means of the carbonic acid. There is, however, still some lime to be removed, as well as a considerable quantity of gummy and albuminous substances. These, and the colouring matter which gives a brown tint to the juice, are in a large degree eliminated by passing the juice through animal-black (char, animal charcoal). This is done by taking the juice from the carbonating-pan into an iron cistern, and there heating it nearly to the boiling-point, afterwards passing it through vessels filled with granulated animal charcoal. The juice finds its way through this gradually to the bottom; and runs out while a fresh supply is poured in at the top. The charcoal has a considerable power of absorbing bodies such as dextrine, and with long time and hot liquor, the action is intensified, and the purification is materially great. This juice to be sent through the charcoal filters is a turbid sticky mass; it is elevated either by a pump or a *monte-jus* into a cistern situated above the series of filters. After the filtration, the juice is in the condition known as "thin"; it is nearly colourless, and is largely freed from lime, and from gummy and albuminous bodies which escaped the action of the lime. In this state, it passes to the concentrating system.

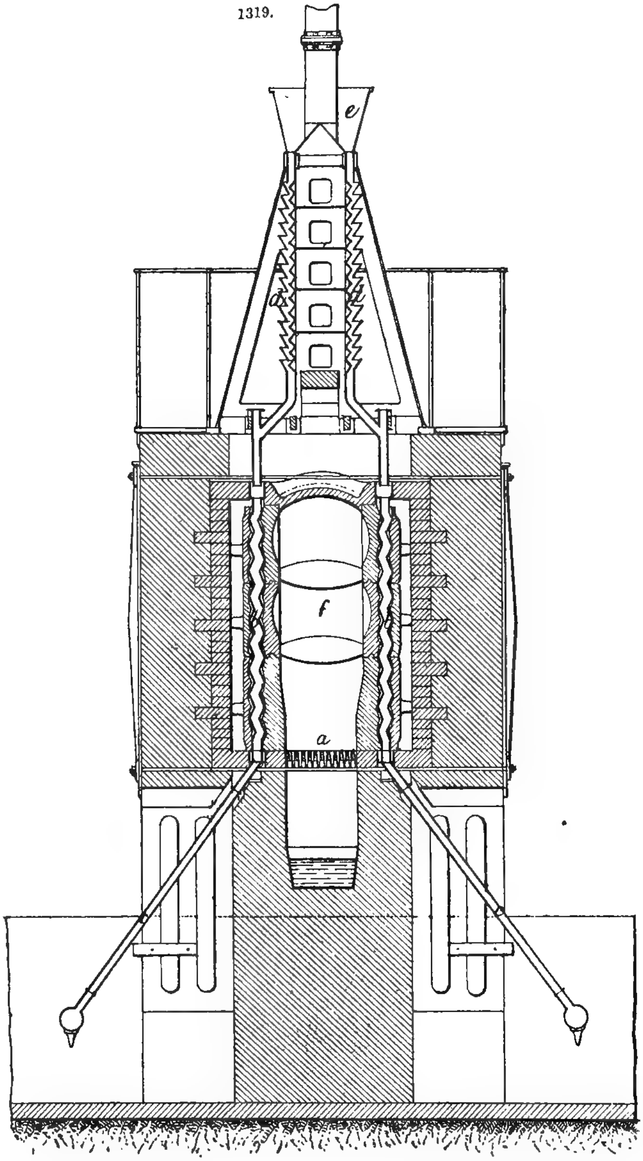
1318.



The filters used are of two kinds. The older sort, known as "Dumont filters," consist of cast-iron cylinders, 6–12 ft. high, and 3 ft. or more diam., open at top, furnished with a false bottom covered with cloth, as well as a man-hole at the level of the false bottom. The cylinder is filled with black, and the juice is run in at top at such a speed that the black remains always covered with a thin layer of liquid. A pipe, leading from the bottom, curves up, in the form of a swan-neck, to half-way up the cylinder.

The other kind, termed "closed filters," are shown in section in Fig. 1316, and as a battery in Fig. 1317. They are 32 in. diam. and 12–16 ft. high; the juice enters by the pipe *a b*, coming from a cistern placed at a higher level, and escapes by a pipe *c* leaving the bottom, and bent up to the summit *d* of the cylinder. This modification possesses the advantage of effecting the filtration out of reach of air and chills, and enables several filters to be in communication, so as to multiply the height of charcoal through which the juice passes. When a filter is judged to be no longer effective, as seen by the questionable colour of the liquor, the supply of juice is stopped and replaced by boiling water, and when the water has driven out the saccharine fluid, the tap *e* is opened at the bottom, the liquor is run out, the black is withdrawn at the man-hole *f*, and the filter is washed, and recharged with new black over which a current of boiling water is passed. The filter is then ready for use again.

1319.



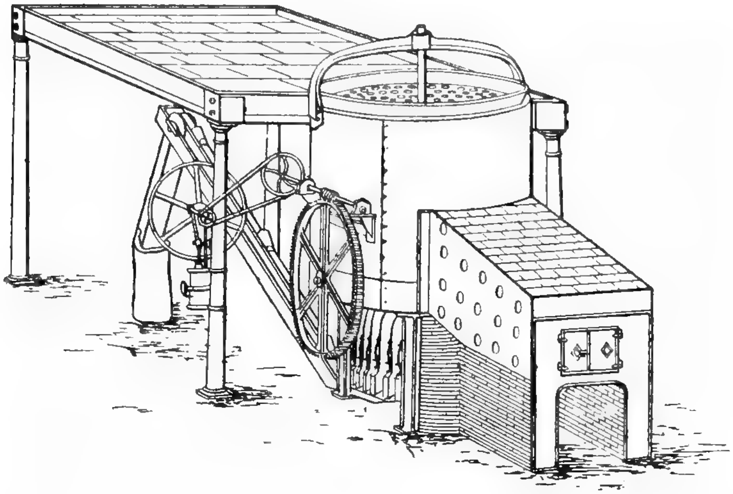
Washing the Charcoal. — The animal charcoal used in these filters is rarely prepared in the sugar-factory itself; but usually it there undergoes a washing operation, as well as a process termed "revivification." The washing is as follows. After having been subjected to fermentation, or to a treatment with alkali at 100° (212° F.), the black is washed with water till it ceases to communicate the least turbidity. Numerous machines have been introduced for carrying out these conditions, the main objects being to cleanse thoroughly, employ a minimum of labour, and avoid disintegration of the black. A typical form is Kluzemann's, Fig. 1318. It consists of a chamber divided by low partitions into compartments *d*, in which slowly revolve arms *c* mounted on shafts *b*, and terminating in flexible iron blades. The black falls from the hopper *a* into the lowest part of the machine; it is successively passed from one compartment to the next by the revolving arms, each time attaining a higher level, finally reaching the upper end *e*, whence it is ejected completely washed. The water admitted by the pipe *f* passes in a contrary direction through the black, and runs out at *g*. The machine is cheap and efficient, and washes about 15 tons per 24 hours.

Schreiber, of St. Quentin, has introduced a novel form of washer, in which the black is placed in contact with a stream of water by means of its own sp. gr., without the intervention of any mechanical appliance to cause its disintegration. The machine consists of a horizontal air-tight cylinder, 6 ft. long, and 28 in. diam., turning in external supports by means of toothed wheels engaging in toothed rings on the cylinder; in the interior of the cylinder, are two paddles or curves, and it is prolonged by a cylindrical part of less diameter. The pipe conveying water enters the cylinder at the axis of this smaller part. The black enters at the other end. In the centre of the cylinder, revolves an endless screw, which catches up the black; and an annular space is left throughout the cylinder for the passage of the water. During the rotation of the cylinder, the black is continually lifted by the paddles by the simple act of rotation, and at the same time a certain quantity of water is taken up, and falls back into the same bath with the black. In this movement, the grains of black traverse the water, and the washing is effected without shock or injury. The paddles are so inclined, that the black entering at one end is propelled along one side to the other end, returning in the same manner along the other side, and escaping finally at the end where it entered. The machine is spoken of in the highest terms.

Revivification.—By "revivification" of the charcoal, is meant the separation from it of those saccharine and other matters which it absorbs in the filtering process, thus rendering it fit for re-use. With this object, it is fermented to destroy the organic matters; washed with acid, with hot water, with cold water, and with steam; dried; and finally calcined in furnaces of very various construction. These all consist essentially of a system of cast-iron or earthenware pipes, heated to dull-redness, and closed at bottom by a method permitting the black to be withdrawn without admitting air, which would immediately cause the combustion of the red-hot carbon. This last condition is the one difficulty, and each maker strives to overcome it in a particular way.

Schreiber's kiln, shown in section in Fig. 1319, consists of a drier, vertical undulating pipes for the calcination, and inclined cooling-tubes terminating in boxes for regulating the discharge of the tubes. It is surrounded with masonry. On each side of the fire *a*, are placed the rows of cast-iron undulating pipes *b*, each composed of three pieces, fitting one within another. They are prolonged downwards by flat cast-iron tubes *c*, serving to cool the black, and forming an angle of 45° with the vertical pipes *b*. At the top, are similar undulating pipes *d*, with lateral openings forming venetian blinds in front, and crowned by a hopper *e* for holding the supply of black for the kiln. This forms the automatic drier. The undulating pipes *b* serving for the revivification are plated inside and out with slabs of fire-brick; these protect the iron from the fire, and regulate the transmission of heat, preventing the temperature exceeding 375°–450° (707°–842° F.), beyond which the black might be vitrified. The black is collected in the hopper *e* above; thence it descends into the driers *d*, enters the revivifiers *b* at about 90° (194° F.), and, when the operation is complete, escapes by the refrigerating-tubes *c*. A fire of coke or other fuel being lit in the furnace *a*, the flame spreads throughout the whole space of the fire-chamber *f* included between the two series of fire-slab coated tubes *b* and an arch at top, passes downwards, divides into two chambers right and left, heats the backs of the tubes, and again rises into a single flue passing through the drier *d*. The kiln is easy to build and manage, and turns out a black of superior quality.

1320.



The Ruelle kiln, Fig. 1320, has several advantages, and differs from most others in its general arrangement. It consists as usual of a series of cast-iron revivifying- and cooling-tubes. The whole of these are arranged in a bunch centred around a vertical axis, and suffer a slow, circular automatic movement of 2 rev. per hour, within a cylindrical furnace flanked by a lateral fire. The black is fed in a thin stream at the upper part of the kiln, and traverses the tubes, which are in turn presented to the fire, so that they are successively brought to a dull-red heat, thus ensuring regularity in the roasting, and avoiding those excesses of temperature which are always to be feared with fixed tubes. The rotary movement enables the discharge to be made automatically; each time a pipe reaches a certain point it meets a cam, which opens the outlet. A little elevator carries away the black as fast as discharged. The waste heat from the furnace circulates beneath a platform for performing the preliminary desiccation. This form of kiln is much used.

The Blaize kiln possesses a most interesting feature in the novel method of manipulating the revivifying-pipes with regard to the escape of the gases and watery vapour during the heating. The black, after washing and vaporizing, still retains some internal humidity, which can only be driven off by calcination. If the kiln is charged with too-wet black, this forms a plug at the top of the tube, preventing the escape of the vapour, which is then forced throughout the column of red-hot black; the latter is thereby decomposed, the carbon is calcined, and the combustible gases escape at the first opening which presents itself, usually between the joints of the pipes, dislodging them, to the deterioration of the kiln, the formation of white char, and the general interruption of the process. Ordinarily these evils are avoided by drying the black as strongly as possible before putting it into the tubes; the moisture then remaining can force a passage between the grains. In the Blaize kiln, the liberation of the vapours is facilitated in the following manner. The heads of the tubes are furnished with a transverse iron bar, composed of two sections, united by a simple covering of sheet iron, and supporting in the axis of the tube another pipe of smaller diameter, made of wrought iron, pierced with slots throughout its whole length, and which, penetrating the mass of black to its hottest part, favours the ready escape of the vapours, and conducts them to the chimney. The black reaches the tubes in a dry state, as it previously passes through the drier,—a chamber traversed by a large number of metallic tubes, through which travel all the combustion-gases, and which can be cleaned by opening the end; there is a trap for discharging the drier. The black has to undergo many changes of position before reaching the floor, thus ensuring its complete desiccation.

The second important feature in the Blaize kiln, is the construction of the tubes, which are of enamelled fireware. Cast-iron tubes wear out rapidly, and unenamelled fireware tubes produce white char, by reason of their great porosity, which allows air to pass. The enamelled tubes do not suffer from the heat of the kiln, as the enamel is put on at a white-red heat, such as is never attained in the black-kiln. Broken tubes can be readily mended by a special composition, and thus rendered as good as new. Moreover earthenware tubes afford a much superior black to iron ones. The construction of the kiln is very simple, and obviates the use of arches, which never withstand fire well. The upper bed and the second floor are formed of square blocks of fireware, through the centre of which pass the tubes. The tubes support the blocks, so that the expansion is uniform, and does not damage the kiln. Broken tubes or blocks can be removed and replaced without pulling the kiln about. The second floor rests upon the cooling-tubes, which are of cast iron, and furnished at bottom with traps and drawers, facilitating the discharge of a set every 20 minutes.

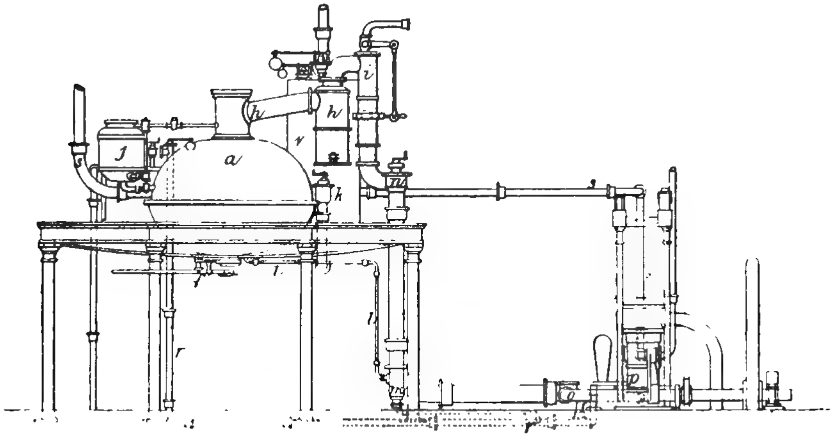
Other forms of revivifying-kiln are described under Refining.

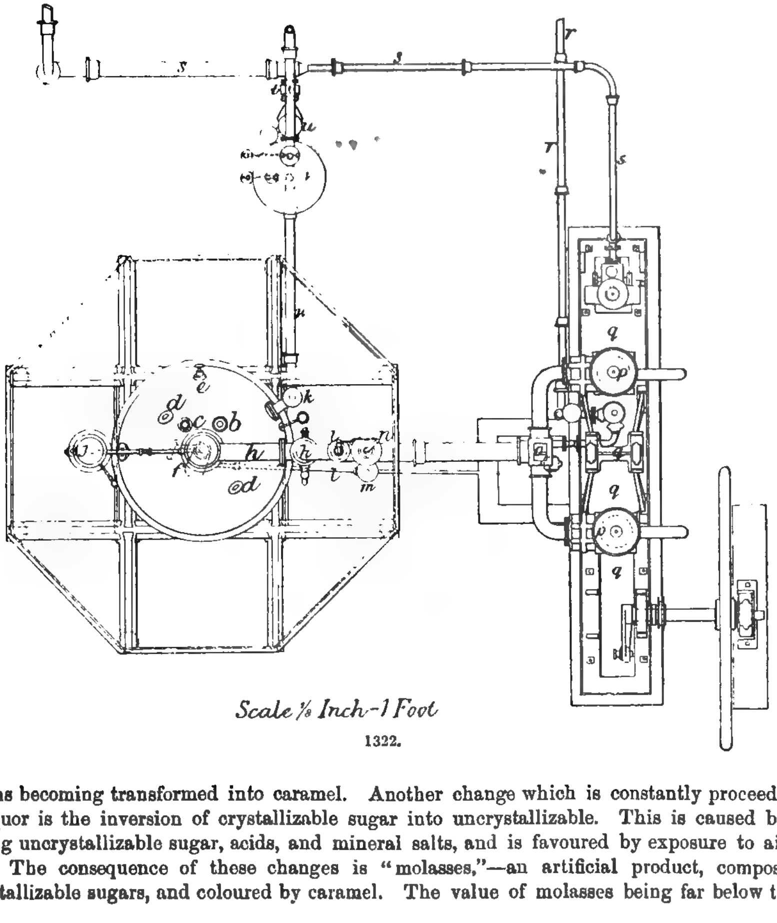
Concentration of the Syrup.—The next operation is the concentration of the "thin" juice, the removal from it of the excess of water, so that the liquid may become sufficiently dense, or saturated with sugar, to enable the latter to crystallize out.

Principles.—While the primary object of concentration is to get rid of useless water and form a solid material, the purification of that material by mere crystallization must not be overlooked. By this act, the particles leave in solution those bodies which are present in too small proportion to admit of their crystallizing out, as well as those incapable of crystallizing. The crystals, freed from their mother-liquor, are considerably purer than the original solution from which they have formed. Crystallization is the property which many bodies (including true sugar) possess of assuming a definite solid form out of a saturated solution when cooled: it is based upon the power of water to hold these bodies in solution in a degree varying with the temperature, this power (in most instances) increasing with the temperature. Thus if a gallon of hot water is made to dissolve as much sugar as it is capable of holding in solution at the temperature exhibited, and this "saturated solution" is cooled, the decreasing solvent power of the water compels the sugar to separate from it in crystals. These crystals are a combination of sugar and water: but the water is chemically combined, and cannot be driven off without decomposing the sugar; consequently this "water of crystallization" is regarded as an integral part of the substance, and the crystals are looked upon as pure bodies. Their size depends partly upon the conditions under which they are formed, these conditions being chiefly the duration of the operation, the bulk of water present, and the agitation or quiescence of the liquor.

In concentrating sugar-liquor to a saturated solution, it is necessary to bear in mind the changes which sugar suffers when subjected to heat. First it melts; then, if the heating be continued slowly and regularly, it parts with successive molecules of water, becoming converted into a number of uncrystallizable non-saccharine bodies, and ultimately into "caramel," a dark-brown substance used for colouring porter and other liquids (see pp. 598–9). This conversion takes place in concentrated solutions, as well as in the dry state. As evaporation proceeds, the mass thickens, and the difficulty of equalizing its temperature increases, with consequent liability of certain portions becoming transformed into caramel. Another change which is constantly proceeding in the liquor is the inversion of crystallizable sugar into uncrystallizable. This is caused by pre-existing uncrystallizable sugar, acids, and mineral salts, and is favoured by exposure to air and heat. The consequence of these changes is "molasses,"—an artificial product, composed of uncrystallizable sugars, and coloured by caramel. The value of molasses being far below that of

1321.





Scale ⅛ Inch-1 Foot

1322.

sugar, the prevention of its formation is one of the chief aims of modern improvements in sugar-making plant.

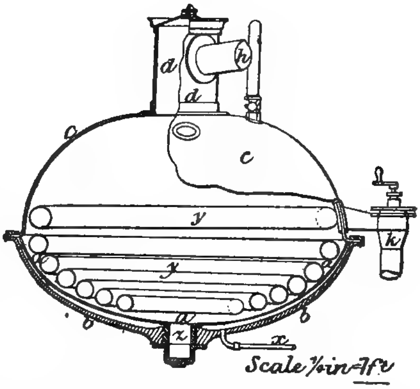
The difficulty of boiling dense liquids is well known. The cause of this difficulty is the lessened ability of the vapourized water to overcome the pressure of the atmosphere, normally amounting to about 15 lb. a sq. in. By relieving the liquid of this pressure, the " boiling " (i.e. the driving-off the watery vapour) can be effected at far lower temperatures, reducing the consumption of fuel, and lessening the danger of burning the liquor. To apply these principles to the concentration of sugar-syrups, the various forms of vacuum-pan have been introduced, in all of which the boiling proceeds *in vacuo.*

The first step with beet-syrup is to boil the watery liquor in a " double-effect " or " triple-effect" apparatus till it marks 25° B., then known as "thick juice." It next goes to a cistern where it is heated to boiling, and is again filtered through animal charcoal, by which more colouring matter is removed, as well as some albuminous bodies that are more readily absorbed from dense than thin liquors. After this second filtration, the juice is brilliant, transparent, and almost colourless, but still contains much water. This is finally removed by boiling *in vacuo.*

In the matter of concentration, the treatment of beet-sugar and cane-sugar are precisely similar; but there are a few variations in the apparatus, the forms employed in the cane-sugar industry being largely of English manufacture, while those used in beet-sugar factories are essentially Continental.

The vacuum-pan and its accessories are shown in elevation and plan in Figs. 1321 and 1322. The pan *a* is mounted on a cast-iron framing, carried by 8 cast-iron columns. Boarding or iron plates form a staging round the pan. The pan is fitted with thermometer *b*, vacuum-gauge *c*, sight-glasses *d*, proof-stick *e* for extracting samples of sugar, slide *f* for discharging sugar, cock *g* to admit steam to clean out the pan, and arm-pipe and receiver *h* to catch any sugar that may boil over. The receiver is fitted with delivery-cock and air-cock for destroying the vacuum when necessary. The condenser *i* is fitted with a perforated pipe and stop-cock, a lever, and an index-plate, to regulate the supply of water for condensing the vapour from the pan; *j* is the measure for regulating the supply of syrup, fitted with stop-cock and inlet-pipe from the filtered-juice tank, a glass gauge to indicate the quantity of syrup, an outlet-pipe with stop-cock opening into the pan, and an air-pipe having a cock communicating with the pan for forming a vacuum in the measure. *k* is a valve for the supply of steam from the expansion-vessel to the worm of the pan; *l*, a pipe for carrying off condensed water from the steam-coil of the pan to the condense-box *m*, which communicates by a pipe with a brick tank from which the feed-water is supplied to the boiler; *n*, air-valve mounted on the air-main, for regulating the communication between the air-pump and the pan; *o*, dividing-box for distributing the flow of air from the pan to the air-pumps; *p*, two 16-in. air-pumps, 1 ft. 9 in. stroke; *q*, 10-H.P. high-pressure beam-engine fitted on diagonal frames, with 11-in. cylinder, 3 ft. 6 in. stroke, and 12-ft. diam. fly-wheel with 6-in. elliptic rim, 4-in. plunger feed-pump, stop-cock, clack-box, copper air-vessel, and feed-water supply-pipe *r* to a Cornish boiler; *s*, pipes for supply of steam to the engine and pan through the expansion-vessel; *t*, sluice-cock for regulating the supply of steam to the mercurial regulating-valve *u*, by which the supply of steam is regulated to the expansion-vessel *v*, fitted with a whistle-valve and safety-valve, to prevent excess of pressure in the worm of the pan; the steam passes from the expansion-vessel through the pipe *w* to the steam-valve *k*, which regulates its admisssion to the pan.

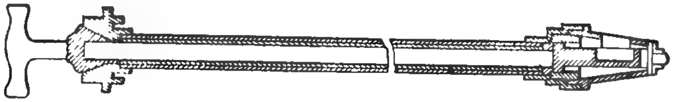
1323.



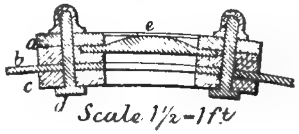
The pan is shown in section in Fig. 1323. The copper pan *a* is fitted in a cast-iron steam-case *b*, with steam-space left between, and is surmounted by a copper dome *c*. The copper and iron pans and the dome are bolted together through their flanges with a wrought-iron ring and bolts so as to be air- and steam-tight throughout. A man-hole *d*, with a ground gun-metal cover, is attached to the top of the dome, from which proceeds the arm-pipe opening into the receiver *h*. A steam-valve *k* opens into the copper steam-worm *y*. This worm gradually diminishes in diameter from the entrance-point at the steam-valve to the exit at the bottom of the pan. A wrought-iron pipe *x* is fitted into the cast-iron pan *b*, to carry off the water from the steam-case; the slide-valve *z* at the bottom of the pan is for discharging the sugar. The dome of the pan is mounted with a vacuum-gauge, thermometer, "sight-glass," and "proof-stick" for testing the concentration of the liquor.

The proof-stick (Fig. 1324) is simply a brass or gun-metal tube, which is driven from the upper part of the side of the vacuum-pan down an aperture made of the same size as the rod. When it reaches the bottom, the tube is twisted half round by the cross-handle, and opens a communication between the end of the tube and the syrup. In the end of the tube is a groove, into which the syrup enters; the handle is half-turned again, the tube is drawn out, and the entrance is closed as before. The liquor can thus be examined without destroying the vacuum in the pan. The sight-glass is shown in Fig. 1325: *a*, gun-metal rings; *b*, vacuum-pan; *c*, leaden ring; *d*, ⅜-in. bolt; *e*, glass plate. Figs. 1326, 1327 show a side-view and plan underneath of a slide. It consists of a gun-metal cup and slide *a*, and wrought-iron lever-bar *b*, fitted with bearings, and of the form and dimensions shown.

1324.



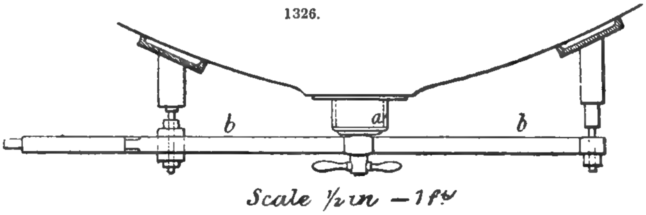
1325.

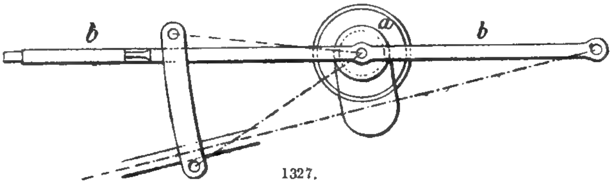


Curing.—The sticky mass of impure sugar-crystals obtained from the vacuum-pan has to undergo treatment which will separate the crystals in a pure white state. The old methods of drainage are described under the head of Cane-sugar; in the beet-sugar industry, centrifugal machines are now exclusively employed for the first operation: their principles and construction are detailed under Cane-sugar and Refining.

First, Second, and Third Sugars.—The centrifugal charged with the dirty crystalline mass is made to revolve rapidly till the colour has changed to reddish, when, without stopping the rotation, a small quantity of *clairce* (pure syrup at 30° B.) is poured in; the result of this is a clear-yellow tint in the whole mass, whereupon dry steam is injected, and soon the sugar becomes perfectly white. This is termed sugar of *premier jet* ("first throwing"). About $\frac{5}{7}$ of the total sugar recoverable in a crystalline form is thus obtained. The liquid flowing away, containing the remaining $\frac{2}{7}$ of crystallizable sugar, besides the uncrystallizable, is run into large tanks, reheated, filtered through animal charcoal, boiled to a stringy consistency, and stored in cisterns during the whole period while the first sugars are being cured. It is then passed through centrifugals, either alone, or with the addition of a little pure syrup, and thus affords a certain quantity of second sugars. The molasses drained off in the centrifugals is stored in immense tanks in a room heated to 40° (104° F.), termed the *salle des emplis* ("filling room"). At the end of a year or so, this molasses is put through a centrifugal, and yields third sugars, with which are crystallized large proportions of saline impurities.

1326.





1327.

Yields.—The results ordinarily obtained in making beet-sugar are:—100 lb. of beet afford 10 lb. of raw (uncured) first sugar, which loses 50 per cent. of its weight in the centrifugal, thus leaving 5 lb. of first sugars. The flowings from the first sugars yield 88½ per cent. of raw second sugars, which, after curing, furnish 37½ per cent. of their weight of second sugars, or 1½ lb. on the 100 lb. of beetroot. The curing of the second sugars gives a very variable quantity of molasses, which renders up 19–20 per cent. of its weight of sugar, or about ½ lb. of third sugars on the 100 lb. of beetroot. The molasses proper contains 50 per cent. of sugar, and as it amounts to 3 per cent. of the beet, it carries away 1½ lb. of sugar on the 100 lb. of beet, bringing the total yield of sugar to 8½ per cent., out of the 10 per cent. originally contained in the roots, the 1½ per cent. difference representing losses during manufacture. Thus, 100 lb. of beetroot give:—

First sugars	5·00 lb.
Second „	1·50 „
Third „	0·50 „
Molasses	1·50 „
Losses: sugar in the pulp	0·50 „
„ „ scums	0·35 „
„ lost in the filters, &c.	0·59 „
Miscellaneous	0·06 „
Total	10·00 „

Thus the average yield of crystalline sugar from the beet is 7 lb. on the 100 lb. of root, or $\frac{7}{10}$ of what the root contains; while the final molasses takes away as much sugar (which is lost so far as its sugar is concerned) as is represented by the actual yield of second sugars.

The Molasses.—The average composition of final beet-molasses is:—Sugar, 50 per cent.; non-saccharine matters, 30; water, 20. Of the 30 parts non-saccharine matters, 10 are inorganic substances, principally potash; the other 20 parts are organic bodies, various acids united to the potash and other bases, compounds derived from the decomposition of the albumen (pectose), "betaïne," and many other substances which have not yet been isolated. These 30 parts of non-saccharine matter contain 5½ per cent. of potash, and 1·8–2·0 per cent. of nitrogen in combination. The annual production of final beet-molasses in continental Europe is estimated at 250,000 tons, representing 125,000 tons of sugar, 13,750 tons of potash, and 4500–5000 tons of nitrogen.

Until recently, the recovery of the 50 per cent. (125,000 tons) of sugar has not been attempted. The ordinary methods of utilizing the molasses have been (1) to convert the sugar present into alcohol by fermentation (see pp. 203–4), and (2) then to carbonize the residuary matters after the distillation of the spirit, and operate upon the ash to obtain the salts, principally carbonate of potash (see pp. 257–9). Some 12,000 tons of potash were extracted from beet-molasses in this way, in 1875, in 18 factories situate in France, Germany, Belgium, and Austro-Hungary. These modes of utilizing the molasses are not the most rational, inasmuch as alcohol can be produced much more cheaply and advantageously from starch. Several methods have been proposed for extracting the sugar contained in the molasses. The most important of these are Dubrunfaut's "osmosis" process, largely adopted in Russia, Germany, Belgium, and France; Scheibler's "elution" process, renowned in Germany; and various plans devised by Seyferth, Manoury, and others.

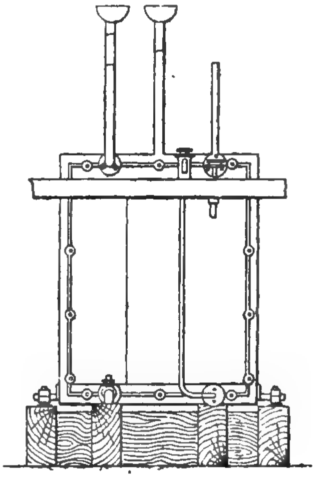
Osmosis.—The osmosis process is based on the same principles as the diffusion method for extracting beet- and cane-juices (see pp. 1842–5), the salts contained in the molasses diffusing much more rapidly through a porous diaphragm than sugar. The difference of time is, however, insufficient to enable direct separation to be made. At the commencement of the operation, the membrane is traversed by much salts and little sugar, whilst later on, the reverse takes place; the operation is, therefore, interrupted when a part of the salts is extracted, so enabling a part of the sugar to be crystallized by evaporation. The second molasses separated from the crystals is of the same composition as the first; this is again diffused, and the operation is repeated until the product is too impure to be worked further. The process is inexpensive, but it causes a loss of nitrogenous matters and potash salts, and it is difficult in some cases to get rid of the washings, which are apt to contain deleterious matters.

The "osmogene" employed in the process is shown in Figs. 1328 and 1329. It consists of two chambers, separated by a suitable diaphragm. One chamber contains molasses, while the other is filled with ordinary water, the two being parted by a septum of parchment-paper. Each compartment is a wooden frame 39 in. wide, 26 in. deep, and about ½ in. thick; 4 wooden stays divide the interior of the frame into 5 compartments, communicating by openings. On each face of the frame, are fitted leaves of parchment-paper, held up by thin cords. The molasses, entering at the bottom, rises in a serpentine into the 5 compartments of the frame, and escapes at the top. A second similar frame, filled with water, is placed in juxtaposition to the first, so that the same sheet of parchment-paper serves to separate the two frames, and consequently the two liquids. This constitutes one "element" (*couple*): several such placed in rotation form the complete osmogene. Circulation is established by channels in the frames, one at the left, below, communicating only with the molasses frames, the other, above on the right, for the circulation of water. The frames are screwed together by long bolts; they usually number 50, sometimes 100. To change the tapes, the screws are undone, and the frames laid on a table. The molasses enters at a temperature of 60°–75° (140°–167° F.), and the water at 85° (185° F.); the density of the molasses is reduced from 41° B. to 30° or 25° B. It might be still further lowered, with corresponding cost in evaporation.

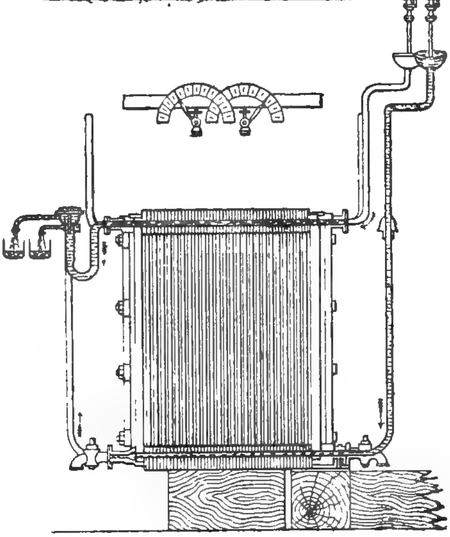
A modification of the osmogene, introduced by Lilpop, Rau, and Löwenstein, of Warsaw, takes the form of Trinks' filter-press. The frames, to the number of 51, rest by means of projections upon two horizontal arms, and are screwed together. The discharge of the apparatus and change of liquids is facilitated by arranging the whole to rotate on its axis.

Elution.—In this process, the sugar of the molasses is converted into tribasic sucrate of lime, by mixing the molasses with about a quarter of its weight of lime, when the mass solidifies; it is treated with water, which removes the organic matters, while the sucrate of lime remains solid. This latter is carbonated (like lime juice), and gives a syrup of 23° B., containing 33·7 per cent. of sugar, and 5·7 of impurities. Much sugar is lost in the washing-water; it has been proposed to remedy this by washing with alcohol of 37°, instead of water. The loss is then much less, and the exosmosis waters contain for 100 parts sugar 131 parts of total impurities. The former process is due to Lair et Bilange; the latter has been named "elution" by Dr. Scheibler.

1328.



Seyferth has modified the elution method by using molasses at 43°–44° B. at a temperature of 30°–33° (86°–91½° F.), filtered through a perforated plate to remove foreign matters. Then 30–40 per cent. of quick-lime,—free from clay, dry, and very finely powdered,—is made into a cream with water, and added to the molasses in little vats. The mass heats to 125° (257° F.); the water evaporates, and swells the bulk 3- or 4-fold. At the same time, ammonia is disengaged, in the proportion of 2·35 parts of steam for 0·008 parts of ammonia, per 100 of molasses. During the swelling-up, the mass is stirred, to prevent it running over. When the operation is finished, the whole is cooled. The vat is opened, and the cake is broken into fragments the size of a nut, without making any powder. These fragments are regularly supplied to large "elutors," having the form of diffusors, arranged in a battery, and surmounted by an outlet-tube for the displaced air, which tube plunges into a sort of condenser for the purpose of retaining the alcohol disengaged with the gases. Alcohol of 35 per cent. is introduced into the elutors from below, and remains for 12 hours upon the lime mixture. It is then drawn off, and replaced by another charge for a further 12 hours. This latter, being but slightly charged, serves for the maceration of a fresh quantity of lime mixture. The sucrate is thus treated 5 or 6 times, till at last it is quite white and pure. At this moment, steam is injected into the elutor. The alcohol which remained imprisoned in the sucrate distils, while the sucrate itself is reduced to a paste, and can be readily drawn off.



1329.

The elution process is now largely used, and furnishes, in the form of sucrate, about 80 per cent. of the sugar contained in the molasses. This sucrate may most advantageously replace milk of lime in the defecation of beet-juice (see pp. 1846–7). Opinions differ as to the relative value of osmosis and elution, the question often depending upon local conditions. The balance would seem, however, to be in favour of the latter. It necessitates expensive plant; but presents the advantages that, when the spirit is evaporated from the leys, the potash salts and nitrogenous matters are recoverable in a sufficiently concentrated form to be immediately available for agricultural purposes.

Manoury's Process.—Manoury has introduced another method for extracting the sugar from the sucrate of lime formed, and has worked it at the Capelle Factory, near Dunkerque, with complete success. The principle is the same as in the German elution process, but the application differs. Into a special mixer, is introduced the molasses with 3 per cent. of lime in the state of milk of lime of 20 per cent. The combination there takes place, and the sucrate of lime leaves it in a granular condition, not larger than a pea, and mixed with excess of pulverulent lime. A bolter separates the powder, while the grains fall into washers with alcohol at 40 per cent. There the sucrate is purified from soluble matters (salts and organic substances), and, from a deep-brown, comes out greyish. It contains about 20 per cent. of lime, and, when dissolved in water, forms a syrup of 26° B., containing an average of 15 per cent. of sugar for 1·30 per cent. of ash. About 100 lb. of molasses give 250 lb. of sucrate. The washers being closed, the loss of alcohol, including revivification, reaches only 2 per cent. of alcohol at 40 per cent. The cost of making the sucrate is placed at 7*d.* per cwt. of molasses. The sucrate is used instead of lime for carbonating raw juice. The apparatus is inexpensive, the manipulation is simple, and the alcoholic purification of the granular sucrate is very perfect.

Cane-sugar (Fr., *Sucre de la Canne*; Ger., *Rohrzucker*).—CULTIVATION OF THE PLANT.—*The Plant.*—The sugar-cane is a kind of gigantic grass, belonging to the genus *Saccharum.* Most botanists ascribe all the sorts of sugar-cane to a single species, *Saccharum officinarum* [*Arundo saccharifera*], supposing all the forms now met with to be varieties induced by cultivation. The best authorities are not absolutely agreed upon this subject, however; and it is probably impossible to arrive at a reliable decision, while the original home of the sugar-cane remains unknown.

Varieties.—Practical ends are served by a knowledge of the characteristics developed by education in the different varieties. Many of these have been raised to the level of distinct species; but it will suffice here to give the names by which they are generally known to planters.

1. The Bourbon cane, introduced into the W. Indies from Bourbon, came originally from the coast of Malabar, there growing as a small-sized, but soft and juicy cane; affected by the change of climate and soil, and cultivation, it so increased in size and richness that it at length entirely superseded the old species.

2. The Otaheite canes are two; the yellow or straw-coloured, and the purple-striped or ribbon. The former and the Bourbon are much alike, if they are not the same variety. With a good soil and favourable season, 1st year's plants are often 12–14 ft. high, 6 in. in circumference, and with joints 8–9 in. apart. Such yield (in Jamaica, Bengal, and the Straits) 2½–3 tons of sugar per acre. They attain maturity in 10–12 months, and require a generous soil, and attentive management. The purple-striped Otaheite cane is often called the Otaheite ribbon cane, in contradistinction to the ribbon cane of Batavia. It is hardy and esteemed, of large size, soft, juicy, and sweet.

3. Batavian canes are four, viz., the yellow-violet, purple-violet or Java, "transparent" or ribbon, and Batavian proper. The "yellow-violet" differs from the Bourbon in being smaller, less juicy, considerably harder, of slower growth, and more erect. When ripe, its rind is thick and pith hard; but its juice is rich and abundant. It grows in inferior soil; its sugar is of fine quality, but less in quantity than from the Bourbon. The "purple-violet," or large black cane of Java, is as thick as the Otaheite, with joints 3–7 in. apart, and is 8–10 ft. high. It yields a very sweet rich juice, but being very hard, it is difficult to crush, and affords a comparatively small quantity of juice. It is very hardy, thriving well in poor dry soils: in Jamaica, it is often planted in the outer rows, to stand the brunt of trespassing cattle. The "transparent," or ribbon cane, is much smaller than the Otaheite ribbon cane. It grows 6–10 ft. high, with joints 4–8 in. apart, and 4 in. in circumference. It is generally planted in light sandy soils, where no other cane will thrive. Though its rind is thick, and its general texture hard, yet it yields a good quantity of juice of excellent quality. The Batavian cane is common in the Straits of Malacca, where it is cultivated by the Malays. The joints are seldom more than 3–6 in. apart. In height, size, and foliage, it closely resembles the yellow-violet; it differs in being softer, more juicy, and less hardy. In a rich soil, it is prolific, and ratoons well; but, on the whole, it is inferior to the Otaheite, while requiring an equally rich soil.

4. Of E. Indian canes, the large red canes of Assam are very juicy and sweet; their sugar is of fine grain and good colour; they are, moreover, strong in growth, and much less apt to fall over than the Otaheite, to which they are equal in size, and in quantity and quality of juice. They can be cut in 10 months from being planted. In Lower Bengal (near Calcutta), and in the Straits of Malacca, a large red cane abounds, which bears a close resemblance to the preceding. The fine red cane of Bengal is much used about Calcutta; sugar made from it by the natives shows a grain of good size, strength, and brilliancy. The black and yellow Nepal canes are large-sized and fully equal in appearance to the Assam. The small-sized canes cultivated in India are very numerous, the most common being the *kajlee* and *pooree.* They are very inferior.

5. The Chinese cane possesses the advantage of being so hard and solid as to resist the white ant and the jackal—two great enemies to E. Indian sugar plantations. It is difficult to crush with the native mill, but bears drought much better than the sorts in general cultivation, producing a profitable crop even to the 3rd year, while the common cane of India must be annually renewed. It is extremely hardy and prolific; during very hot seasons, it remains uninjured in every respect. By September, it reaches 12 ft. in height, 3 in. in circumference, and with joints 6–8 in. apart. These, cut in October, may be planted out during a tolerably severe winter. The variety is well suited to India, though far inferior to the Otaheite, wherever that cane can be cultivated successfully. It is rarely more than 1–1¼ in. diam., but is sweet, and makes fair sugar. The Chinese assert that it is better adapted for making sugar-candy than any other cane. This must not be confounded with the Chinese cane experimented upon in Demerara in 1854–5, which was *Holcus saccharatus* (see Sorghum-sugar); it gave 3 or 4 crops a year, but its annual aggregate yield fell short of common cane.

6. The "elephant" cane of Cochin China has been stated to reach a height of 11 ft. and diameter of 7 in. in 6 months. It is there only cultivated for chewing, but might succeed better elsewhere. In a good soil, it requires 2 years to reach 10 ft. in height; after 5 or 6 years, it may reach 16–32 ft. In Mytho, it is cultivated in humid alluvial soils on a considerable scale. It possesses a very brittle rind, breaking into small fragments when passed through the mills.

7. The Straits Settlements grow eight kinds of sugar-cane, foremost among which is the Salangore. This is one of the finest canes known, attaining a weight of 25 lb., a length of over 13 ft., and a diameter of 3 in., under favourable conditions. It "ratoons" better than any other kind in the Straits, and has been known to yield there 40 *piculs* (of 133⅓ lb.) of granulated undrained sugar on 1 *orlong* (1⅓ acre) of ground as 3rd ratoons. As "plant canes," they have given an average of 65 *piculs* of granulated sugar from each *orlong*, or 6500 lb. to the acre, sometimes increasing to 7200 lb. They grow firm and strong, remaining much more erect than the Otaheite; and afford abundance of juice, which is sweet, easy of clarification, boils well, and produces a very fair sugar of bold and sparkling grain. The Salangore cane has been introduced into Brazil and the British and French W. Indies. Planted at 2 yd. by 2 yd., and properly manured, in 5–6 months it forms such a thick vigorous growth as to keep down weeds. The clumps yield 25–40 canes, thus producing a weight per acre much in excess of ordinary canes. As many as 16 clumps have been cut from 40 sq. yd., giving a nett weight of over 800 lb., or at the rate of more than 80,000 lb. to the acre, while the ordinary canes vary from 20,000 to 60,000 lb.

8. The S. Pacific Islands produce a number of forms of cane which are strictly local. Cuzent enumerates seven kinds in the Society Islands. On the flanks of some of the mountains, two other varieties are met with: they are both small. Canes growing in the Pacific Islands are said to yield more juice and considerably more crystallizable sugar than the bulk of those raised in our Colonies; and the Otaheite [Tahiti] canes cultivated in the W. Indies degenerate in course of time, and should be renewed by the importation of fresh stock from the Pacific groups, and perhaps New Guinea. The Sandwich Islands are accredited with 35–40 distinct varieties. One of these, grown on 30 acres of good land under irrigation, gave an average yield per acre of 12,000 lb. (6 hhds.) of No. 16 sugar. It is hardy, and grows freely up to 2000 ft. in its native country.

9. H. Prestoe recently published an official report, describing the 14 best W. Indian varieties of cane, among 32 surviving kinds of a larger number sent from Mauritius; 18 seem to be distinct varieties, deserving of culture, as possessing, in one way or other, superiority over the few sorts at present in cultivation, and among which the yellow Otaheite takes by far the largest place. Some of the new varieties are peculiar for length of joint, and some for length of joint united with stoutness. One is remarkable for these combined with very soft tissue. It also bears drought well, and is prolific. A richer and moister soil will improve all. Purple and purple-striped canes are generally admitted to be preferentially adapted, by their hardihood, to the poorer drier soils; but they have a strength of tissue which gives increased trouble in crushing. There are remarkable exceptions, however. There is no reason to doubt that, with selection and nursing, superior and fixed qualities can be obtained in sugar-cane, as freely as they have been in beet and other agricultural crops in Europe and America.

More recently, particulars have been published of three new varieties, named "Caledonian Queen," "Green Salangore," and "Violet Salangore." The first is close-jointed and extremely vigorous, and the ready way in which the length of joint and diameter of cane are affected by manure, indicates great variability of habit, and suggests gigantic growth under the influence of rich alluvial soil. The Green Salangore is the freest-growing of all, except the giant Claret cane; and its erect habit is even more striking than in that sort. In respect of length of joint and diameter of cane, it is equal to it, thus being the largest yellow cane grown in Trinidad. The foliage is completely deciduous, so that "trashing" is reduced to a minimum. The Violet Salangore has the habit of erect growth most strongly developed, besides being distinctly the longest-jointed and tallest, with a full average diameter.

The erect habit in these two Salangores is a character which, considering the influences most conducive to a large yield of sugar, is of importance. One of the most commonly observed facts on a sugar-estate is that canes grown erect (and therefore enjoying full sunlight and air) are yellow, and "full of sugar," whereas canes lying on or near the ground (and thus deprived of light and air by their erect companions) are green and deficient in sugar. The erect or decumbent posture of the canes is in a measure dependent on the soil, and on the kind of culture they are treated to, especially when young; but, under any circumstances, a marked disposition to maintain an erect habit of growth is an obvious advantage in respect of the sugar yield.

With regard to the several varieties already introduced from the East, as well as the three now newly brought into notice, there has not been any means for testing their specific habit of growth and sugar yield under extended cultivation.

The planter should make a selection of the two or three best sorts adapted to his estate, and not confine his attention to a single kind, however superior its qualities may be, for experience has proved that one class of cane, grown for successive seasons over many years, suffers material deterioration. The occasional exchange of new varieties therefore becomes imperative, in order to secure the maximum results that the land is capable of affording.

Structure and Development.—The sugar-cane has a knotty stalk, and at each knot or joint is a leaf and an inner joint. The stole or "stool" is divided into two parts: the first is formed of several (5–7) peculiar joints, placed very near to each other, and having rows of little points at their surface, which are elements of roots and are called radicles; the whole forms the primitive stole. The joints are likewise endowed with several rows of points, elements of roots, which develop themselves when requisite, and form, with the joints whence they issue, the secondary stole. The roots issue from the development of the sap-vessels, which are disposed in concentric rays round each point, on the surface of the joint. They are very slender, almost cylindrical, scarcely ever more than 1 ft. in length, and have a few short fibres at their extremities.

The number of joints on the stalk or cane proper varies from 40 to 60 (even 80 in Brazilian); but there are much fewer in the Otaheite, whose internodes or so-called "joints" are 8–9 in. long, while the finer specimens of Brazilian are but 2–3 in. The joints vary much in dimensions. The knots of the canes are rings ⅛–¼ in. wide; 4–5 rows of semi-transparent points occupy their circumference, and a circular semi-transparent line divides the outer from the inner joint. At the upper part of this, is a slight circular hollow, called the "neck," terminated by the leaf belonging to the joint. The inner joint performs the most important function of the plant from an economic point of view; in it, the juice, after undergoing various modifications, arrives at the condition which gives it its value as a sugar-yielder. On every joint is a bud, which encloses the germ of a new cane.

The sap-vessels are large, and number more than 1500. The buds always grow alternately on the opposite sides of the joints. The semi-transparent ring which forms a line of demarcation between the outer and inner joints is the weakest part of the cane, and where it is most apt to break. The rind consists of three distinct parts: the rind properly so called, the skin, and the epidermis. The rind is formed of sap-vessels, ranged in a parallel direction, on a compact circular surface. The skin, which is very thin, is at first white and tender; it becomes green and then yellow, as the joint approaches maturity. The epidermis is a fine and transparent pellicle, which covers the skin.

Under very favourable circumstances, immediately after the first development of the cane-joints which form the secondary stole, the bud of the first of these joints may throw out its radicle roots and form a second filiation on the first; the bud of the first joint of this second filiation also sometimes forms a third; the second and third soon become very nearly as forward as the first, and, like it, form canes.

The first joint requires 4–5 months for its entire growth, and, during this time, 15–20 joints spring from it in succession. When the leaves of the first two or three joints have died away, there are then 12–15 leaves at top. In its natural state, the cane has at this stage completed its growth, and arrived at the usual period of its flowering; if it blooms, the principle of life and generation passes entirely to the development of the parts of fructification. At this time, the joints which spring forth are deprived of their bud, and the sap-vessels, with which they were supplied, pass into the leaf; whence it happens that, as the number of these vessels is constantly diminishing, the joints in a similar proportion become longer, and their rind thinner. The last joint, which is called the "arrow," is 4–5 ft. long; it is terminated by a panicle of sterile flowers 18–20 in. high. If the period of flowering is delayed by cultivation, the principle of life passes to the generation of new joints, and this continues till the sap-vessels of the stole become woody, and do not afford a passage to the juices. Under cultivation, very few canes flower at all; exceptions occur on some soils, when the canes are planted early, and their vigorous growth is suddenly checked.

Range.—The sugar-cane has a wide range, succeeding in almost all tropical and sub-tropical countries, and reaching an elevation above sea-level amounting to 4000 ft. in the S. Pacific, and 5000–6000 ft. in Mexico and S. America. It is cultivated in many parts of the level country in India and China as far as 30° or 31° N. lat. Its exact geographical range may be more conveniently studied in the section on Production and Commerce.

Climate.—The sugar-cane thrives best in a warm moist climate, with moderate intervals of hot dry weather, tempered by refreshing sea-breezes. Its most luxurious development occurs on islands and sea-coasts, leading to the supposition that the saline particles conveyed to it by the winds are beneficial; but perhaps the exuberance of the plant in such situations is due to the moisture which accompanies the sea-breezes, even in the hottest and driest weather. The cane attains its greatest perfection within the tropics: cold in any degree opposes its growth and development, hence it can be cultivated but little in Europe. A singular change in the nature of the juice is occasioned by frost. While the frost continues, the low temperature prevents fermentation setting in; but should a thaw intervene, viscous fermentation takes place, and will prevent the crystallization of the juice if subsequently concentrated. In the upper districts of India, frost frequently does great harm to the cane crops. Rain at the proper season is equally necessary for cane-culture, though it may be to a great extent replaced by irrigation; but rain when the canes are maturing, if in great quantity, may do much mischief. As the canes are approaching maturity, 2–3 months of hot and fairly dry weather are exceedingly beneficial, bringing the juice to the highest degree of sweetness, and assuring a large yield of fine sugar; slight showers at long intervals serve to maintain the vigour of the plant without appreciably weakening the juice. In the case of vegetation being renewed by rains after a drought, if it occur in a locality where frost is not to be feared, it will sometimes be advantageous to leave the canes on the ground much later than usual, as the juice will gradually become much richer than it can be immediately after rain.

Should an alternation of sunshine and rain be followed by long-continued drought, the growth of the plants will be checked, and there will be a disposition to arrow. If cut now, the juice will be of good quality, but deficient in quantity, owing to the small size of the canes. When a drought sets in only a short time before commencing to reap the crop, the effect is eminently beneficial, causing an inspissation of the saccharine contents of the cells by the evaporation of their water. But if the drought should continue beyond the time necessary to produce the effects just mentioned, the stems assume a red and scorched appearance, and not unfrequently split; the canes then are said to be "burnt." The juice is reduced in quantity, and its quality is altered. In extreme cases, it is strongly acid, but it varies much in this respect. Frost will also cause canes to burst.

Soil.—Decomposed granite in the Straits Settlements affords really desirable land for sugar culture, being well fertilized by a proportion of decayed vegetable matter. In both E. and W. Indies, there abounds a kind of soil called "brick-mould," which is considered most advantageous for sugar-planting. It is a mixture of sand and clay, in such proportions that air and water can penetrate to some depth with facility, thus constituting a marl which can be worked with ease. Its property of retaining moisture, even in the hottest season, is remarkable; while in heavy rains, the water escapes quickly where drains exist. Deep black moulds are less suitable for cane-culture, tending to produce exuberant plants, rather than a rich and plentiful juice. Some of the very best sugar is produced on limestone soils, though they do not promise great fertility. In the Straits Settlements, Demerara, Louisiana, and other places, it often occurs that lands are strongly impregnated with saline matter, which causes the cane to grow most luxuriantly, but affects the juice (and consequently the sugar made from it) very prejudicially. Where salt is present in the land, as from the overflowing of tides, the course to be pursued is, after banking out the tide and properly draining, to plant Indian corn, Guinea corn, or Guinea grass for 2–3 years, until the saline matters have become in a degree exhausted; canes may then be planted without fear.

Manuring.—The object of manuring is to supply to the plant those chemical constituents which the soil is deficient in. The sugar-grower's efforts must be directed to the production, not of the tallest and stoutest canes, but of the greatest possible quantity of crystallizable sugar.

Composition of the Canes.—Before discussing what cane-manures should consist of, it is necessary to know the composition of the canes to be grown, and of the soils to grow them.

The average composition of a fully-developed sugar-cane is:—

Water	71·04	Derived almost wholly from the air.
Sugar	18·02	
Cellulose	9·56	
Albuminous matter	0·55	
Fatty and colouring matters	0·35	
Salts soluble in water	0·12	Derived from the soil.
" insoluble "	0·16	
Silica	0·20	
	100·00	

Therefore 1000 tons of cane take up from the soil rather more than 4 tons of mineral ingredients, and about 1 ton of nitrogen is required to form their albuminous matter. Manures deal only with the materials supplied through the soil, except in supplementing the amount of nitrogen. The nature and relative proportions of the mineral ingredients are ascertained by analysis of the ash of the full-grown entire cane. Much discrepancy exists in the analyses of cane-ash hitherto made, which is due in part to variety of soil, different ages of the plants, and omitting the leaves.

Subjoined are some analyses of cane-ash, by Dr. Stenhouse :—

	Trinidad.				Berbice.			Deme-rara.	Gre-nada.	Jamaica.		
	1	2	3	4	5	6	7	8	9	10	11	12
Silica	45·97	42·90	46·46	41·37	46·48	50·00	45·13	17·64	26·38	52·20	48·73	54·59
Phosphoric acid	3·76	7·99	8·23	4·59	8·16	6·56	4·88	7·37	6·20	13·04	2·90	8·00
Sulphuric acid	6·66	10·94	4·65	10·93	7·52	6·40	7·74	7·97	6·08	3·31	5·35	1·94
Lime	9·16	13·20	8·91	9·11	5·78	5·09	4·49	2·34	5·87	10·64	11·62	14·36
Magnesia	3·66	9·88	4·50	6·92	15·61	13·01	11·90	3·93	5·48	5·63	5·61	5·30
Potash	25·50	12·01	10·63	15·99	11·93	13·69	16·97	32·93	31·21	10·09	7·46	11·14
Soda	..	1·39	..	..	0·57	1·33	1·64	..	..	0·80	..	..
Chloride of potassium ..	3·27	..	7·41	8·96	..	..	..	10·70	11·14	..	16·06	0·84
Chloride of sodium ..	2·02	1·62	9·21	2·13	3·95	3·92	7·25	17·20	7·64	4·29	2·27	3·83

The first seven were all fine canes with the leaves; No. 8 had no leaves; No. 9, but few; No. 10 was in full blossom, and had been manured with pen-manure; No. 11, old ratoons, manured in the same way; No. 12, young Mont Blanc canes, manured with pen-manure, guano, and marl.

The principal substances, therefore, required to be provided in an available state in a cane-soil are potash, silica, phosphoric acid, sulphuric acid, lime, and magnesia, besides a certain amount of nitrogen beyond what the plant can secure from the atmosphere. The oxides of iron and of manganese are, perhaps, also essential.

The relative importance of each substance is a difficult problem to solve. But the mineral ingredients are constantly found in the same relative proportions. It must not be forgotten, however, that the sugar-cane possesses a power of absorbing a quantity of salts from the soil, far in excess of its needs, and to the detriment of its juice. This is referred to under Soil (p. 1863), and is illustrated in Nos. 3, 7, 8, 9, and 11 of Dr. Stenhouse's samples.

Composition of Cane Soils.—The composition of cane soils may be illustrated by two analyses by Dr. Phipson, one (A), of a soil from an estate in Jamaica under canes for the first time; the other (B), from a Demerara plantation worked for more than 15 years consecutively :—

	A.	B.
Moisture	12·25	18·72
Organic matter and combined water	15·36	6·03
Silica and insoluble silicates	48·45	68·89
Alumina	13·80	2·50
Oxide of iron	6·72	2·60
Lime	0·99	0·08
Magnesia	0·29	0·25
Potash	0·11	0·10
Soda	0·70	0·09
Phosphoric acid	0·10	0·03
Sulphuric acid	0·30	0·03
Chlorine *	0·51	trace
Oxide of manganese, carbonic acid, and loss in analysis ..	0·42	0·68
	100·00	100·00
Nitrogen (in organic matter)	0·31	0·05

* The quantity of chlorine is unusually high, which is accounted for by the proximity of a salt spring.

While A possesses everything requisite to grow canes for a number of years, B is fast approaching exhaustion. Attention is called to the greater amount of organic matter (humus), nitrogen, lime, and phosphoric acid in A, and to the important fact that the quantity of lime (0·08) in B is far below that of the magnesia (0·25). This last is a very bad sign, so much so that the degree of exhaustion which a soil has undergone can to a great extent be ascertained by comparing the relative amounts of lime and magnesia. The lime disappears by prolonged cultivation of the cane, whilst the magnesia remains as it was. When the lime has diminished so much as to be present to the extent of only 0·1 per cent., and then amounts to but one-third of the magnesia (though originally the lime was higher than the magnesia), the crops of cane will fall off year by year, and most careful manuring will be necessary to regenerate the soil.

Manures obtained from Foreign Sources.—The only manures fit to be used on a partially-exhausted soil are good stable-manure, well-fermented farmyard dung, or manure made from night-soil. These are natural products, and not only contain all that the plant requires, but in the proper state for assimilation. Superphosphates have little beneficial effect upon graminaceous plants (including the sugar-cane and the cereals); and though excellent special manures have been compounded, nothing can equal dung and night-soil. Dung is precluded from wide use by reason of its bulk, but a product is now prepared from night-soil and urine which well compares, in composition and fertilizing qualities, with concentrated farmyard manure. It is got by evaporating excreta as nearly as possible to the dry state; as it holds only 12–16 per cent. of water, its transportation can be effected as easily and cheaply as with guano. Analysis shows it to contain all the ingredients of rich farmyard manure in a concentrated state, and in the same assimilable form. It is manufactured by the Urban Manure Company, at Bloxwitch and Churchbridge, and is eminently adapted for long-worked cane soils.

Perhaps the best method of using the acid superphosphate manures would be to mix them intimately with one-quarter their weight of good Peruvian guano, and one-quarter their weight of cane ash, and apply the mixture at the rate of 5–8 cwt. an acre, according to the mechanical condition of the soil, and its more or less effective drainage. A good mixture for most soils consists of Peruvian guano, cane ash (or burnt begass), and stable manure or compost heap, to which mixture one-quarter its weight of gypsum might be added. This last ingredient supplies lime, which has already (p. 1864) been alluded to as of primary importance. Lime is equally well supplied by chalk, unburnt limestone, or broken sea-shells; it should never be applied in the caustic (burnt) state.

Sulphate of ammonia and nitrate of soda act as powerful stimulants, but the plants feel a great relapse shortly afterwards. Moreover, nitrogenous manures do great harm in another way, by increasing the albuminous matters in the cane-juice, to the double detriment of the sugar, first by reducing the amount of sugar in the plant, and next by destroying a portion of the sugar in the already-extracted juice during the process of manufacture.

Manures Produced on the Estate.—The waste produced on a sugar estate consists of the following materials:—(1) The "trash," or dead leaves which are stripped from the canes during growth, as well as the "tops" which are not used for planting; (2) the "begass," or crushed cane from which the juice has been (more or less perfectly) extracted; (3) the "feculencies" collected in the clarifiers, &c.; (4) the "dunder," or wash-waters, containing salts in solution and other matters. To these must be added the night-soil and dung accumulated on an estate.

The leaves should be hoed in as fast as the trashing (p. 1867) proceeds; but this cannot be done in localities frequented by the white ant. In such cases, the vegetable matter must first be fermented in tanks under sufficient moisture to repel ants, and then ploughed or trenched in between the rows of canes. The same applies to the waste cane-tops.

The begass may be carried back to the fields by the carts which bring in the canes, and immediately ploughed or trenched into the soil. But the general plan is to use the begass for fuel, and return only its ashes to the soil. Burning reduces the ashes to an insoluble condition, and their value is greatly diminished. The question of returning the begass to the soil depends upon the circumstances that the estate requires both manure and fuel, and that the fresh begass will afford either one or the other (but not both); consequently the one not so supplied must be derived from other sources. The highly-concentrated form in which cane manures are now supplied, and the invention of furnaces for burning undried begass (p. 1876), are inducements to adhere to the current custom. Thus only the ash of the begass can be counted on as manure. This amounts to about 5 cwt. from each 100 tons of cane crushed and burned; its manurial value is 8*s.* a cwt. It should be preserved with the other waste under a shed out of the rain till used. There will probably be an additional 5 cwt. of ash from other sources (trash, wood, &c.), worth about 6*s.* a cwt.

The feculencies and skimmings, say 6 tons (from 100 tons of cane), if pressed as soon as collected, yield 3 tons of juice and 3 tons of cake; this cake, dried, with or without previous fermentation, yields ½ ton of dry nitrogenous manure, worth 3*l.* The sediment of fermenting-vats, also containing some nitrogen, say 4 cwt. when dry, would be worth 10*s.*

The "dunder," being to the extent of ⅔ used over again daily in making up the wash, would leave ⅓ to be dealt with as manure, say 800 gal. or 4 tons (from 100 tons of cane). It would dry to about ½ ton, and be worth about 3*l.*

Green-soiling, Rotation, Fallows, and Tillage,—"Green-soiling" consists in planting beans. lucerne, indigo, or other plants, between the cane-rows (when canes are first planted), and ploughing them in whilst they are green and succulent; this has a powerful fertilizing effect. Indigo planted by a drill (in regular lines), just at the commencement of the rains, may, in 2 months after, be uprooted, laid along near the roots of the young canes, and moulded over. If cut to within a few inches of the ground, when they have attained a good growth, they will furnish another fine bushy plant before the end of the rains; this may then be rooted up and moulded over as the first. The indigo-plant is continually appropriated to this end by the natives of India, although not until the colouring matter (see Dyestuffs—Indigo, pp. 858–61) has been extracted, and the plant becomes partly decomposed. The greatest good can only result from ploughing in plants whilst quite green and succulent, and the best time for the operation is just before they blossom. In Demerara, the castor-oil plant (see pp. 1380–2) is highly esteemed for the purpose; and the same may be said of the pigeon-pea (*Cajanus indicus*) in the W. Indies and Australia.

Rotation of crops as a means of refreshing the soil has long been known and applied in European agriculture, and some sugar-planters have at last appreciated the advantages to be derived from it. In Mauritius, it is now becoming the general custom, after the land has borne canes for 2 seasons, to plant it with maize (Indian corn), arrowroot, manioc (cassava), or peas, allowing a period of 3 years between the cane crops.

Fallows and tillage may be considered together, as there is very little good in allowing land to lie fallow (unoccupied by any crop) without subjecting it to thorough tillage, so as to open it up, and expose it thoroughly to the action of the air. Green-soiling is probably more beneficial than merely allowing the land to lie fallow. In Demerara, rotation is rarely practised, the same land growing canes for many successive years; but care is taken to manure well, and to make constant interchange of plants between different estates.

Laying-out an Estate.—The laying-out of a sugar estate is a much more complicated affair in British Guiana than elsewhere, as it mostly includes provision for drainage and irrigation. Here the plantations are mostly narrow rectangular strips of land, with a water-frontage varying from 100 to 300 Rheinland *ruthe* or roods (of about 12⅛ ft.). Every estate is bounded by 4 dams: the front dam excludes the sea, river, or canal; the back dam excludes the bush-water, which, in heavy weather, would inundate the cultivation. The clay thrown out in forming the adjacent canals or trenches affords the material of which the dams are formed. Along each of the remaining sides, runs a dam from front to back, usually termed "side lines"; they serve two contiguous estates, and prevent the influx of water from the sides. The dams answer the purpose of a road round the estate; but the produce is brought to the buildings (often situated in front) by canals. The arrangement of the navigation system is very simple. From front to back, through the centre of the estate, runs a dam called the "middle walk," with a canal on each side, termed "central canals," wide enough to admit two punts abreast. The dam forms a path for the cattle that draw the punts. At intervals, branch canals strike off at right angles, and proceed to within a rood of the draining or side-line trenches, which are parallel and adjacent to the side dams. These branch canals constitute the transverse boundaries of the fields, and navigation canals thus lie on three sides of every field, and admit of canes being carried by a short path to the punts. On some estates, there is only a single central navigation canal. These canals are principally supplied by the rain, but in protracted droughts, and especially when they are shallow, they are liable to run short of water: hence, whenever access can be got to creek-, lake-, or bush-water, it is brought from behind to supply the navigation system. In other instances, salt water has to be taken in from the front. The drainage of the estate is equally simple. From back to front, and immediately adjacent to the side-line dams, run the 2 main draining-trenches, generally dug considerably deeper than the navigation canals. The small drains, again, cut at distances of 2–3 roods apart, commence within a bed of the middle-walk side of the field, and terminate in the side-line draining-trenches, having a fall in that direction. The small drains are thus at right angles to the main draining-trenches. In the front dam, the sluices or "kokers" are placed. Sometimes there is one on an estate, but generally two, one at the end of each draining-trench. The main draining-trenches are generally connected by a trench running behind the front dam.

Drainage.—The proper drainage of a sugar estate is a most important matter. This is especially the case in localities which possess no natural means of taking off the surplus water, as for instance, the flat lands of British Guiana. Open drains are at present the only ones in use on almost all sugar plantations. Besides being very ill adapted to the purpose, they entail great expense yearly to keep them clean. But perhaps their greatest disadvantage is the extent of land they occupy. On an estate of 500 acres, no less than 50 acres are lost in drains alone. Moreover, however well constructed, the sides are perpetually slipping in, and greatly preventing the flow of water. Other drawbacks are the inability to use the plough or tilling-machine, and the loss of fine earth which is being continually swept away during rainfall.

The remedy lies in the adoption of tile drains on ordinary soils, and stone box drains on heavy clays. The objection to these is the large first outlay necessary; but this would be more than compensated for by the value of the land rendered available for culture, and the reduction in the cost of maintenance.

Irrigation.—In part of Upper India and in Peru, it is impossible to cultivate even the common native cane without constant irrigation; in the W. Indies, Straits Settlements, and many other parts, the cane is grown without other moisture than that obtained by rain. But though long periods of dry weather very frequently occur, when planters are in despair at the ruin and destruction of their crops, few recognize the value of irrigation.

River water generally contains silica, potash, oxygen, and other substances conducive to fertility, independent of the extra matters contributed during heavy rains. In the dry season, when irrigation is necessary, the water would only supply those substances ordinarily held in solution. The sugar-cane thrives luxuriantly where the change of water constantly renews the supply of dissolved silica. The potash abstracted is also restored to the soil by irrigation. In irrigating during hot weather, there is an additional benefit derived from vapour passing up through the foliage.

Propagation.—The propagation of the sugar-cane is effected exclusively by cuttings from the stems. For this purpose, none but the healthiest and most vigorous canes are selected; neglect of this point results in disease and deterioration, and, even with every care, it cannot be continued indefinitely with impunity, and sooner or later new plants have to be introduced. Every part of the stem having a perfect "eye" or bud will put forth a new plant, and it sometimes becomes necessary to utilize every portion of the sound canes in this way; but where there is room for choice, preference is generally given to the few joints nearest the leaves, usually termed the "cane-top." This is not the case in Louisiana; preference is there given to the main stalks, and tops are used only for economy sake. When planted, the eyes at the joints commence to spring forth, and at the same time a number of roots are thrown out around the whole of each joint. As the development of the shoots advances, the parent cutting gradually dies and decays, while the young shoots become furnished with perfect roots of their own.

Planting.—The land having been brought into a fit condition to receive the cuttings selected, planting is the next operation. This naturally divides itself into several distinct sections:—

Lining-out and Holing.—Regularity in the rows of cane is very important. This is attained by "lining-out" the fields with great care, by means of long lines and poles (much the same as for Coffee, see p. 693). Each field of 5–25 acres is first divided into sections by tall poles, placed say 100 ft. apart on each side. Between these are stretched long tapes carrying pieces of rag, fastened at the distance apart which the holes are intended to be. Small stakes are then driven in at the rags, each stake occupying the centre of the hole to be dug.

The distances apart and dimensions of the holes are subject to no rule. Very often, the holes are made 2 ft. apart in rows 3 ft. asunder, but much depends upon the soil and climate. Common dimensions in the W. Indies are 15–18 in. sq., and 8–12 in. deep; in Guiana, 3 ft. sq. at top, diminishing to 14 in. at the bottom, and about 8 in. deep, each plant having an area of 4–5 ft. sq. There is a growing disposition to replace hand-dug holes by furrows turned by the plough, the latter effecting a great economy of labour; ploughing is universal in Louisiana. It is generally necessary to still retain the lining-out.

Setting out the Cuttings.—The number of cuttings to be placed in each hole, or each 2 ft. of trench, is 1–4, according to their vitality and the prospects of their striking root. With good sound cuttings, 2 placed at about equal distances from parallel sides of the hole suffice; when 3 are set out, they are laid parallel with each other, and with two sides of the hole; when 4 cuttings are necessary to ensure a plant from each hole, they are commonly arranged in a square, corresponding with the sides of the hole. The three usual plans of setting out in trenches are (1) end to end at a little distance apart in one continuous straight line, (2) overlapping each other zigzag fashion, and (3) side by side obliquely across the trench. It is preferable to plant too heavily rather than too lightly.

The cuttings, when in the holes or trenches, are covered with a thin layer (say 1½–2½ in.) of earth. They thus lie sheltered from direct sun-heat at the bottom of a more or less deep hole, which forms a receptacle for moisture. The time for planting is governed by the character of the local seasons; no absolute rule can be laid down for it.

Moulding and Banking.—In about a fortnight, young sprouts push themselves up through the covering of earth; these are immediately "moulded" round with some of the soil still remaining from the hole or trench. This is repeated at intervals, as the plant grows, till the hole or trench is filled up, and further till the stem of the cane is "banked up" for a certain distance, to favour its retaining an erect position.

Weeding and Trashing.—Simultaneously with the moulding and banking, the land should be thoroughly weeded with a hoe. As the plants progress, "trashing" also becomes necessary. This consists in removing from the stem every dry and fading leaf. In rich land, it requires to be frequently resorted to during the wet season, but may be done at longer intervals when the rains are over. Constant trashing admits to the plants that abundance of light and air which is essential to the production of a heavy crop of sugar. Green living leaves must on no account be removed. Equally demanding removal when too numerous, are the suckers thrown up by the roots; in Louisiana, however, they are encouraged. Both leaves and suckers should be buried in trenches between the cane rows, and covered with a thin coating of earth; there they decay, and form excellent manure for the growing crop.

Ratooning.—The first crop from newly-planted cuttings is called "plant" canes; when these have been cut, the stole or "stool" sends up another growth of canes, which are termed "ratoons." The first crop of ratoons is designated "first ratoons," and so on progressively. Ratoons annually diminish in length of joint and circumference; but they are said to yield richer juice and finer sugar. On some soils, it is found best to depend chiefly on ratoons. A very general practice is to plant a proportion ($\frac{1}{3}$) of the land in annual succession. The stoles remain in the ground, and vacancies are filled up as they occur. By constant ratooning, the produce of sugar per acre, if not equal to that from plant canes, yields, perhaps, in the long run, quite as much profit to the grower, if the relative proportions of the labour and expense attending the two methods be considered. As soon as the canes are cut, the land intended for ratoons requires attention. The trash should be buried with other manure about the roots of the plants, the earth around being well loosened and cleared of all weeds, before the rains set in. The number of ratoons depends much on the productiveness of the soil. A good rule in most cases is to replant when ratoons give only 1–1½ hhds. of sugar per acre.

In some countries, as Bengal, good ratoons are never met with. First ratoons may be allowed, but white ants swarm in the old roots, and do mischief to the growing canes; whereas when planted yearly, or every 2nd year, the stirring which the land receives drives them away. In replanting, the old roots should be burnt, and the cuttings planted between the rows of the former crop.

Harvesting.—When the canes are ripe and ready for the harvest, they are cut with hatchets as close to the stole as possible; thus new vigour is given to the ratoons that are to spring from the old root. The top is discarded; it may perhaps suffice to cut off only one joint with the top, from canes grown on very dry soils; but otherwise, two should be cut, for if they are immature, their juice will injure the sugar, instead of augmenting its quantity. All leaves are also stripped off; rat-eaten or otherwise damaged canes should be thrown out.

The canes, being cut, are tied into bundles for the convenience of taking them to the mill. On the mountains, they are carried by mules; in some parts, the bundles are rolled down the steep places, or shot down wooden spouts; in the plains, they are conveyed in carts, drawn by oxen, mules, or road engines, to enclosures near the mills; in Guiana, by flat-bottomed punts on canals which intersect the plantations for this purpose; wire-rope tramways have also been used to a limited extent.

Windrowing.—In Louisiana, frost so often occurs before the harvest is complete, as to have resulted in the adoption of a method of keeping the cut canes uninjured, termed "windrowing." For cane that is waiting for the mill, the usual plan is to throw into one furrow 2–4 rows of cane, so that the tops of the last will cover the butts of the preceding. The proper way to windrow cane for seed is first to throw to the centre of the water-furrow one or two furrows of dirt from each side; a harrow is then run over to pulverize it thoroughly, and give the cane a soft bed, at such an elevation that the cane cannot be injured by water standing on it. Upon the cane, 2–4 more furrows of dirt are thrown, to protect it from the cold. Some are in favour of "round mats," or standing the canes upon their butts on a dry piece of land, and throwing dirt around the outside to the height of 3–4 ft.; the cane from about ½ acre is usually put in each mat. The addition of a square wooden tube, running up through the centre for ventilation, prevents dry rot. The "flat-mat" method (laying down in beds about 15 ft. wide, on elevated ground, to the depth of 2–4 ft., then lightly covered with earth) is much more common and popular.

Diseases and Enemies.—Some of these are common to both wild and cultivated cane; but others are developed upon the latter alone, and have originated in defective culture, improper or insufficient manuring, or unsuitable conditions of climate or soil.

Rats.—Rats are one of the most troublesome pests, as they gnaw the standing canes, thereby admitting air, and setting up destructive changes in the juice. Some estates have been rid of rats by rearing numbers of the mongoose; it will thrive in any climate that will grow sugar-cane.

Ants.—In some localities, white ants are a great nuisance. They are driven away by tillage; and tops or cuttings soaked for a few minutes in water tainted with petroleum will never be attacked by them.

Pou blanc.—*Pou blanc*, or more properly, *pou à poche blanche*, is a collective name applied to two species of "louse" (*Icerya sacchari* and *Pulvinaria gasteralpha*). Their ravages are familiar to the planters of Mauritius and Bourbon, and specimens of one of the species have recently been discovered in Queensland, upon canes grown from joints newly imported from Singapore. In dry hot weather, these insects frequent the roots of the canes, and do much injury to the fresh rootlets, thereby greatly retarding the growth of the plants. The young run about on the green shoots and leaves, until they find a suitable spot where they may fix themselves for life. They are armed with a long sharp probe, which they introduce into the new sap-wood, and suck away the juices of the plant, sometimes till they have quite destroyed it. They spread rapidly, and are very tenacious of life. Dr. Icery found that washing the canes with alcohol killed the insects at once, and he recommends a solution formed by boiling a mixture of sulphur and lime in water. The insects rarely appear on healthy well-developed canes, and though these remedies may prove useful for checking their ravages for the moment, their complete extermination will only be secured by attention to all the conditions required by the plants. W. Bancroft Espeut believes that the "rust" described further on is caused by these insects, being in fact abrasions produced by the young feeding on the surfaces of the leaves. The "waxy" powder which is usually described as coating the fully-matured insects, is ascribed by him to the saccharine juice of the cane. It is this exudation which forms the great attraction to the ants, in quest of which the latter scrape the lice incessantly with their mandibles, till the victims die of starvation.

Borers.—The term "borer" is applied generically to the caterpillars or "grubs" of a number of species of moths, beetles, and other insects; they are sometimes (in America) also called "worms," which is a misleading name, from its being correctly and more generally applied to a distinct class. One of the most common is *Proceras sacchariphagus*, long dreaded in Ceylon, and the cause of great destruction in Mauritius, since its introduction in 1848. Two kinds prevalent in British Guiana are *Sphenophorus sacchari*, and the *tacuma*, a large species of *Rhyncophorus*, very like *R. Zimmermanni*, but not identical with it; another is *Phalæna saccharalis*, which produces 6 generations in a year. The grub of a beetle (*Tomarus bituberculatus*) also has recently given much trouble in that colony. The list might be greatly extended. The habits of the grubs appear to be nearly identical in all cases. They are provided with powerful mandibles, and their mouths are armed with lance-like instruments, which enable them to pierce the silicious (flinty) outer rind of the cane. Once within the soft juicy mass of the interior of the cane, they effect its destruction with extreme rapidity, and the juice is rendered useless. Among the means to be adopted against these insects, are the encouragement and cultivation of their natural enemies. Principal among the latter are ants, which attack the insects both in their caterpillar state, whether just issued from the eggs or about to enter the "pupal" condition (commencing to spin their cocoons), and in their perfect or "imago" form, i. e. as moths or beetles. Turkeys and the smaller insectivorous birds devour enormous numbers of the "grubs" (caterpillars). Bancroft Espeut has had singular success in cultivating other enemies of these insects, notably the Ichneumonidæ ("lady-bird beetles"), by planting a hedge of the Congo or pigeon pea (*Cajanus indicus*) around each field, and growing the bonavist bean (*Dolichos Lablab*) and pigeon pea on fallow fields, ploughing in the latter as a green-soil manure afterwards. When the estate is quite overrun with the caterpillars, it may be necessary to burn all vegetable matters likely to harbour them. But this should be avoided if possible, as it entails the destruction of the best manure the land can have (see p. 1865). The abundant application of lime to the soil is generally very beneficial in destroying the insects, besides its manurial value (see p. 1864). A widely-adopted plan is to cut off and burn the first shoots that spring from the planted cuttings; these are allowed to grow for about three months, by which time the grubs will have congregated on them. The second crop of shoots soon appears; and their skins are tougher, and better able to resist the attack of the grubs which have escaped burning. Not only borers, but many other injurious insects are propagated on the canes year after year. Hidden in the cane-tops, are the chrysalides of the insects, which in due course are transformed into moths and butterflies, whose eggs supply a new swarm of caterpillars and grubs, and thus the evil is constantly maintained. Obviously, therefore, great good may be gained by ridding the cane-tops of all vermin before planting. A very simple plan is to soak the cuttings for 24 hours in water which is sufficiently hot to destroy larvæ, without being hot enough to injure the germinating powers of the plant. More effective is the use of antiseptic preparations, as they attack parasitic growths which would be unaffected by mere warm water. Carbolic acid (see pp. 671–80) has long been used. Dr. Bancroft has published exact directions for a treatment which he has adopted with success: as follows:—(1) Carefully clean the joints of the cuttings entirely from trash (leaves), (2) immerse the cuttings for 24 hours in a mixture of 1 lb. carbolic acid to 50 gal. water heated to a degree that the hand can bear; (3) immerse the cuttings for a few minutes in milk of lime, made by mixing 2 lb. slaked lime with 1 gal. water; (4) spread the cuttings out to dry in the sun, and turn them occasionally, for one day before planting.

Rust.—A disease termed "rust" has been noticed in Queensland, the Malay Archipelago, Mauritius, the Society Islands, and Bahia. It is characterized by a dark-brown or reddish granular, incrustation, which makes its appearance on the leaves and stem, and which M'Lachlan has determined to be due to the punctures of a minute *Acarus* (mite), which exists upon the diseased cane in myriads. The creature looks very like a *Tyroglyphus*, though its habits do not altogether accord with those of that genus. A black-spored fungus is eventually produced by the red spots on the leaves; this is regarded by Berkeley as a new species (*Depazea sacchari*); he considers that it merely occupies the already-destroyed tissues. The Bourbon canes suffer much more than any other variety. Prof. Liversedge, of Sydney University, considers that rust is not a disease, but rather a result of an existing diseased condition. This he ascribes to bad cultivation, want of drainage, and improper manuring, to which must be added, in some instances, unsuitability of climate and poverty of soil.

Smut.—In Natal, the canes are attacked by a kind of "smut" (*Ustilago sacchari*), analogous to the well-known disease which affects the cereals of this country; it is entirely due to faulty cultivation.

Yields of Canes and Sugar.—Statistics of the cane and sugar production of certain districts are useful for reference in drawing conclusions as to the results of new processes.

Barbados.

1 ft. sugar-cane weighs about ¾ lb.
1 clump ,, ,, ,, 54 lb.
1 ,, ,, yields ,, 4 gal. juice.
4 gal. juice ,, ,, 4 lb. muscovado sugar.
1 acre ripe cane (holes 6 ft. × 5 ft.) yields 1452 clumps.
1452 clumps cane yield about 5808 gal. juice.
5808 gal. juice ,, ,, 5808 lb. sugar.
1 acre, planted 6 ft. × 5 ft., at 50 lb. to the clump, will give 72,600 lb. or 36 tons ripe cut cane, or 2½ tons raw sugar.

Louisiana.

1 acre yields 44,000–60,000 lb. cane.
The average cost per 2200 lb. is 2½–5 dol.
The density of the juice varies from 6° to 10° B., and averages 8°–8½° B.; 8° B. is equal to 14·4 per cent. pure sugar per 100 lb. juice, or 12·96 lb. sugar for the 90 lb. juice contained in 100 lb. canes; 8½° B. would mean 15·33 per cent. pure dry sugar.
1240 gal. juice at 8½° B. produce 1048 lb. sugar, and 480 lb. molasses; with the best modern machinery, more sugar and less molasses is got.
1 gal. juice at 8½° B. weighs 10·62 lb.
1240 gal. ,, ,, 13,169 ,,
100 lb. cane contain 90 lb. juice.
12,345 ,, yield 11,111 ,,
11,111 lb. juice at 8½° B. should give 1700 lb. sugar.
The actual yield of combined sugar and water of crystallization is 14·89 per cent.
11,111 lb. juice therefore afford 1655 lb. sugar and molasses.
Of the 1655 lb., 1173 lb. are sugar, and 482 lb. molasses.
Thus 427 lb. sugar and molasses are lost in the manufacture.
11·8 lb. cane give 1 lb. sugar and 0·48 lb. molasses.
10·5 lb. cane would have given 1 lb. sugar and 0·66 lb. molasses, if no loss had occurred.
7·26 lb. cane would give 1 lb. sugar, if there were no loss, and no molasses produced.
1 acre will grow 13,000–45,000 canes.
The length of the canes varies from 3 to 8 ft.
,, weight ,, averages 10 oz. per ft.
Canes 4½ ft. long, weighing 3 lb. each, and growing 350 per row of 100 ft., will give 61,125 lb. canes per acre.
Planters require 35–55 lb. cane to make 1 lb. sugar and 0·66 lb. molasses.
The average for the State is 2·25 lb. sugar and 1·50 lb. molasses from 100 lb. cane.
Thus 100 acres give 6,000,000 lb. cane, affording 135,000 lb. sugar, and 90,000 lb. molasses.
But 6,000,000 lb. cane, if no loss occurs in manufacture, can give 571,428 lb. sugar, and 380,952 lb. molasses.
And, if made into first, second, &c., sugars, could yield 750,000 lb. white sugar, and 140,000 lb. molasses.
While the same cane would make 867,510 lb. concrete sugar.

Mauritius.

1 barrel cane juice weighs 530–544 lb.
1 ,, ,, yields about 95 lb. sugar
1 acre cane produces 3500–5500 lb. sugar.

Egypt.

1 acre cane affords about 500 lb. refined sugar.

Juice from 100 lb. Cane.

100 lb. cane giving juice at 10° B. will yield :—

4·714 gal. juice at 50 °/₀ extraction.	7·543 gal. juice at 80 °/₀ extraction.
5·185 „ „ 55 „ „	8·015 „ „ 85 „ „
5·657 „ „ 60 „ „	8·486 „ „ 90 „ „
6·128 „ „ 65 „ „	8·958 „ „ 95 „ „
6·600 „ „ 70 „ „	9·430 „ „ 100 „ „
7·071 „ „ 75 „ „	

Composition of Cane-juice.—Before detailing the many processes and apparatus used in making sugar, an idea must be gained of the nature and characters of cane-juice. Mention has already been made of the structure of the sugar-cane. Within the cells, is contained a sweet watery juice, a sugar-water holding a variable quantity of organic and mineral matters in solution. This is the juice which is extracted for the purpose of being made to yield its sugar. The nature of the ingredients composing it is not liable to variation; but their proportions fluctuate with the soil and climate, the age of the cane, the portion of the cane affording the juice, and other circumstances. R. H. Harland states the composition of some cane-juices expressed from ripe canes grown in Queensland, as follows :—

	Guinghan Cane	China Cane.	Mixed Canes.
Density at 15½° (60° F.)	11·5° B.	10·5° B.	11·6° B.
	per cent.	per cent.	per cent.
Crystallizable sugar	19·50	16·40	18·30
Uncrystallizable „	0·25	0·41	0·45
Ash (soluble salts)	0·70	1·11	0·37
Other organic matters	1·17	2·51	3·14
Total solid matters	21·62	20·43	22·26

Samples of unripe cane-juice showed :—

	I.	II.	III.
	per cent.	per cent.	per cent.
Crystallizable sugar	8·60	7·76	7·24
Uncrystallizable „	3·10	2·30	2·50
Ash (mineral matters)	0·21	0·25	0·34
Unknown organic matters	1·27	1·74	2·89
Total solid matters	13·18	12·05	12·97

In general terms, cane-juice consists of about 81 per cent. of water, 18 of sugar, 0·6 of organic matters, and 0·4 of inorganic (mineral) matters; further, about 0·5–0·6 per cent. of the sugar in the juice of ripe canes (it is much greater in unripe ones, as shown) is uncrystallizable. These substances are very intimately combined, but the juice is not of one constant quality throughout the whole cane. Thus planters reject the tops of the canes before extracting the juice. Further, the juices contained in the soft central (medullary) part of the cane are much richer in sugar than those of the nodular (the "knots") and cortical (the rind) portions. Conversely, the saline and organic matters (other than sugar) are in increasing proportion in the harder parts of the cane; when an extra yield of juice, therefore, is obtained by the exhaustion of the harder portions, the quantity is at the expense of the quality. This has a bearing upon the question of the relative advantages of mills extracting only 60 per cent. and those getting 85 of the 90 per cent. of juice usually present in the cane.

It is now necessary to separately consider each component part (or group) of the raw juice.

The Crystallizable and Uncrystallizable Sugar.—The artificial conversion of uncrystallizable into crystallizable sugar remains an impossibility, though the latter can be readily "inverted" into the former. From experiments by Harland, it would seem that in the growing or ripening plant a conversion of uncrystallizable into crystallizable sugar does take place, the proportion of the former being markedly decreased in juice expressed 8 days after the cutting. The occurrence of uncrystallizable sugar in the juice works a twofold mischief:—(1) The uncrystallizable sugar is itself a loss, i.e. it has no value as sugar; (2) its existence in the syrup so affects the remainder as to hinder, if not prevent, the recovery of an equal quantity of the crystallizable sugar in a saleable form, for the liquid containing the altered sugar has a treacly consistence, and cannot be conveniently deprived of its water by evaporation to such a degree as will leave the unaltered sugar in a saturated solution capable of clean crystallization on cooling. Practically, therefore, it may be said that every 1 lb. of sugar rendered uncrystallizable means a loss of 2 lb. of crystallizable sugar.

The chief cause of alteration in the sugar is fermentation of certain constituents of the juice, viz. the organic matters other than the sugar. The essential conditions are mainly access of air to the juice, and a moderately high temperature. Consequently fermentation begins in the living cane, when injuries (gnawing by rats) admit air into the cells. Artificially, it is set up the moment the juice is extracted, and is maintained by the heat necessary for carrying on the manufacture, augmenting as the time is prolonged and the heat increased. Acids also provoke fermentation; they are nearly always present in a free state, as shown by the juice giving a red colour to litmus-paper. Hence the importance of rapid treatment at low temperatures, and with the least possible exposure. Fermentation does not commence in the juice while still in uninjured canes. In Louisiana, sound canes may be kept for 3–4 months after cutting, the only result being the loss of a portion of the water of vegetation. In the Philippines, sound cut canes may be kept for a week at least, despite the high temperature of an Eastern tropical summer. This seems to indicate that canes could be kept and transported long distances without undergoing loss of crystallizable sugar; but it applies only to sound canes, and the result might be different in cases where the rind was cracked or eaten into. Obviously something also depends upon the climate, as in the W. Indies and Demerara, the juice must be expressed within 48 hours after cutting, to prevent an excessive inversion taking place; this is retarded by antiseptics, and salicylic acid is now much used with this object.

The quantity of sugar in a sample of cane-juice may be approximately ascertained from its density. This is observed by a hydrometer. As the indications of this instrument refer to the proportion of solid matters in the liquid, without reference to their character, they need correction for the solids other than sugar. The following table will be found useful for this purpose:—

Baumé Degrees at 25° (77° F.).	Weight of Sugar per cent. of the Juice (indicated).	Weight of Sugar per cent. of the Juice (actual).
4	2·8	2·6
5	4·9	4·8
6	7·8	7·4
6¼	8·5	7·9
6½	9·1	8·6
6¾	9·8	9·2
7	10·5	9·9
7¼	11·1	10·5
7½	11·8	11·1
7¾	12·4	11·7
8	13·1	12·3
8¼	13·7	12·9
8½	14·4	13·5
8¾	15·2	14·2
9	15·9	14·9
9¼	16·5	15·5
9½	17·2	16·1
9¾	18·0	16·7
10	18·8	17·4
10¼	19·6	18·0
10½	20·4	18·7
10¾	21·1	19·4
11	21·7	20·0
11¼	22·6	20·6
11½	23·0	21·1
11¾	23·7	21·6
12	24·4	22·7

The Mineral Matters.—The quantity of mineral salts in the juice of canes best fitted for sugar-making is about 0·29 per cent. of the liquid. They are found in greater proportion in the head than in other parts of the cane. The nature of the soil has a marked influence, and to it the variations in the figures must be referred. The principal mineral matters are potash, soda, lime, and iron, as oxides, carbonates, chlorides, sulphates, biphosphates, and silicates; with these, are salts of alumina and magnesia. The annexed analysis of cane ash shows the average proportions of the most important:—

Potash and soda	18·83 per cent.
Lime	8·34 „
Oxide of iron	1·99 „
Silica	11·48 „
Alumina, magnesia, and acids in combination with the bases ..	59·36 „

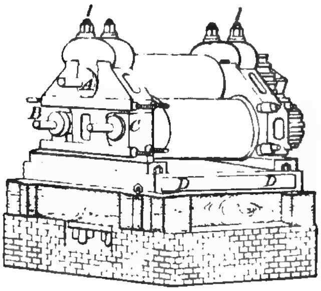
The Organic Matters.—The vegetable (organic) matters contained in cane-juice (excluding the sugar itself) may be divided into 3 groups:—(1) Substances which communicate a milkiness to the liquid, and are with difficulty precipitated from its upper layers on standing, but may be easily and almost completely separated by filtration, juice thus filtered having the property of keeping nearly 24 hours without undergoing fermentation; (2) albuminous material capable of coagulation by boiling, or even by heating to 80° (176° F.), and precipitable by strong acids without being re-soluble in excess; (3) albuminous bodies not coagulated by heat, but precipitable by alcohol and by lead acetate, and soluble in alkalies and acids (even tannic acid). Juice which has been heated and filtered may be kept perfectly fresh for some few hours, at a temperature of 30° (86° F.). At the end of this period, a thin pellicle is seen, and on the next day, a slight cream covers its surface, and the colour changes; but it is only at the end of the second day that fermentation positively shows itself. It thus appears that it is sufficient to rapidly heat the newly-extracted juice, and filter it immediately, in order to have a limpid liquid, which can be kept for a considerable time without very great alteration. Further, these substances develop acidity in the juice, and are one of the principal causes of the formation of uncrystallizable sugar. When they are eliminated, acidity is only feebly increased by the action of heat.

Extraction of Cane-Juice.—The juice in the cane exists in the plant enclosed in little cells, which are surrounded and protected by lignose (woody matter), the latter forming about $\frac{1}{10}$ of the total weight of the cane. The liberation of the juice may be effected (1) by rupturing these cells, so that their contents flow out; (2) by combining the crushing process with maceration in water; (3) by utilizing the membrane of the cells as a means of allowing the escape of the sugar and other "salts" in solution, by the process known as "diffusion."

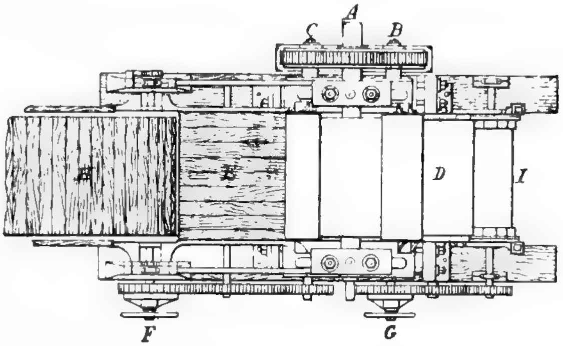
Cane-mills.—An account of all the introduced or proposed forms of mill for crushing sugar-cane would fill a large volume. Practical ends will be served by describing the typical forms.

Rousselot's 3-roller mill, as made by Fawcett, Preston, & Co., is shown in Figs. 1330–1332. The bed-plate D is seated on a strong timber framework, through which the large bolts I (Fig. 1330) pass, allowing the top roll to lift a little when any extraordinary strain occurs. The canes pass by the carrier H (Fig. 1331) down the slide E, through the rolls, and the begass emerging at D is taken away by a carrier worked by the drum I. The ordinary frame of cast iron is not exposed to tension. The resistance of the canes between the rolls A B C is taken from the top roll A through the cap and bolts, and compresses the frame, while the tendency to separate the bottom rolls is controlled by the horizontal tie-bolts; for all practical purposes, the frame might be made of oak instead of iron, as the working strains are thrown upon the wrought iron, instead of being borne by cast iron, as in other mills. The 3 cast-iron rollers are keyed on to the wrought-iron shafts. The "returner-bar," or "knife," or "trash-turner," as it is variously denominated, is a flat or curved plate, placed at a distance of 2¼–3 in. below the bottom of the top roll, made to touch the circumference of the front roll, and to stand off about ½ in. from the lower back roll, so as to allow the juice to run down. The mill shown in Fig. 1332 is composed of two cast-iron frames *d*, secured to the bed-plate *e* by bolts at the four corners. Seats are prepared on the frames *d* for carrying the brasses for the shafts of the rolls *a b c*. The bolts *i j* pass through the frames and bed-plate and through the timber *k*, and take the strain of the top roll, and the bolts *h*, of which there are 4 for each frame, take the strain on the caps *g f*. In this manner, the strain is borne by the wrought-iron bolts instead of being thrown on the cast-iron frames, enabling more juice to be extracted with safety than can be done with the ordinary cast-iron frame. The yield of sugar from the cane crushed in this mill at the central factory in St. Lucia, during the season ending in May 1881, is stated at 8 per cent. of the weight of the cane; the cane there seldom gives juice of 10° B., yet by the careful use of a Rousselot mill and the necessary adjuncts, with a

1330.



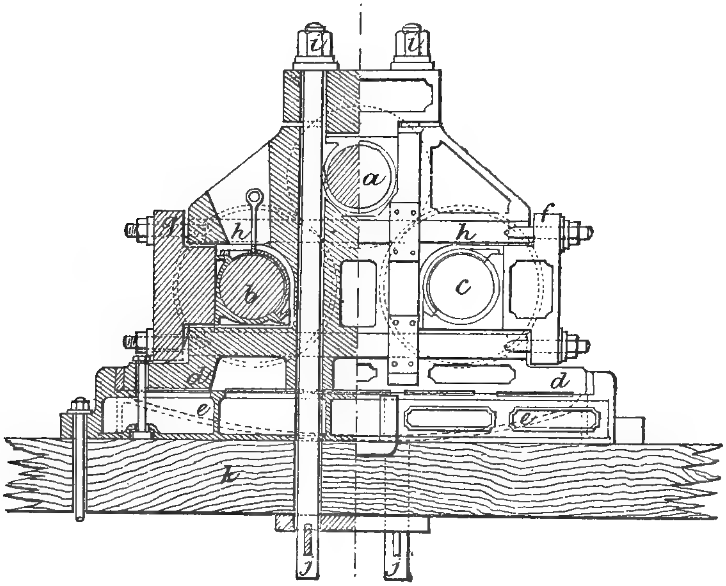
1331.



very limited consumption of animal black, 10,000 tons of cane give 800 tons of sugar of superior quality, averaging in London 25*l.* a ton.

Formerly the returner-bars were much slighter than those ordered and supplied at present. When canes are passed through a mill without choking, everything works smoothly; but from the moment that a cane doubles up, trouble begins. The rolling friction of the mill is a light matter; but the sliding friction in the confined space between the top roll, the front roll, the returner-bar, and the back roll, is very great. If the returner-bars are slight, they bend by the pressure, and the jaw is relieved. The bar is taken out and straightened, and work is resumed. A pressure of 50 lb. a sq. in. drives the mill when there is no jamming; but 80 lb. is required when it is "braked" by accumulation of trash between the rolls and the returner-plate; orders are daily given for stronger returner-bars, so that where the massive rolls are "braked" with trash, that becomes hot and hard with friction, the resistance has to be overcome, and returner-bars are made to resist the force of a 60-H.P. engine, geared 20 to 1, and making 40 rev. Many engineers contend that those who are trying to increase the yield in juice by very slow movement are in error, and recommend experiment in the direction of lighter and repeated crushings, combined with maceration. By using two mills of moderate proportions, more effective work is said to be obtained, because there is less sliding friction; and it is questioned whether the extra quantity of juice obtained by the extra force of a large mill is not at the expense of the quality.

1332.



On the other hand, the rolls of the mills erected at Aba-el-Wakf, by Eastons and Anderson, in 1872, measured 48 in. diam. and 5½ ft. long, had a surface-speed of 27–36 ft. a minute, took a feed 15–18 in. deep, and did excellent work. A comparative trial of a small rapid and a large slow mill on the same estate in Porto Rico, under like conditions, is interesting. The rapid mill had rollers 22 in. diam. by 48 in. long, and an average speed of 24 ft. a minute; the slow mill had rollers 36 in. diam. by 66 in. long, and an average speed of 9 ft. The rapid mill ground cane in good season, yielding juice of 10° B., and having 10 per cent. of woody fibre; the slow mill had average good canes, a little over ripe and dry, yielding juice of 11° B., and 14 per cent. of woody fibre. The results were:—

RAPID MILL.

Quantities.	Canes in lb.	Juice in gallons.	Juice in lb.	Sugar in lb.	Molasses in lb.	Total Green Sugar.
387 loads ..	1,170,332	65,442	702,092	72,081	37,464	109,545
1 load ..	3,024	169·1	1,814·44	186·25	96·80	283·05
100 lb.	100	5·59	59·9	6·16	3·20	9·36
1 gal... ..	nearly 18	1·00	10·73	1·10	0·572	1·672

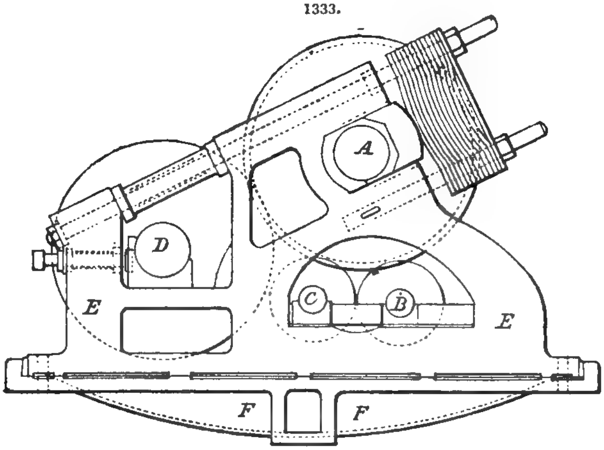
SLOW MILL.

Quantities.	Canes in lb.	Juice in gallons.	Juice in lb.	Sugar in lb.	Molasses in lb.	Total Green Sugar.
629 loads ..	1,369,275	98,350	1,063,163	138,750	64,944	203,694
1 load ..	2,177	156·36	1,690·25	220·6	131·67	352·27
100 lb.	100	7·18	77·61	10·13	4·74	14·87
1 gal... ..	13·07	1·00	10·81	1·41	0·66	2·07

The loss in the begass of the rapid mill was 7·53 per cent.; in that of the slow mill, 2·47, or a difference in favour of the latter of 5·06 per cent.

The De Mornay mill (Fig. 1333) presents various advantages, and will doubtless be more widely adopted in future. In Cuba and Demerara, it is unknown; but it has been manufactured for S. America by Fawcett, Preston, & Co., and worked there with great success. The canes enter between the rolls A B, and are carried onwards by the roll C, inclining upwards until they are grasped by A D. There is no returner-bar in this mill to cause abnormal friction and resistance, and no sliding or rubbing of the top roll on a mass of crushed cane. It is stated that this mill, when properly constructed and proportioned, will grind cane with 50 lb. steam when the ordinary 3-roller mill fitted with a returner-bar requires 65 lb., or the difference between a 15- and a 20-H.P. engine.

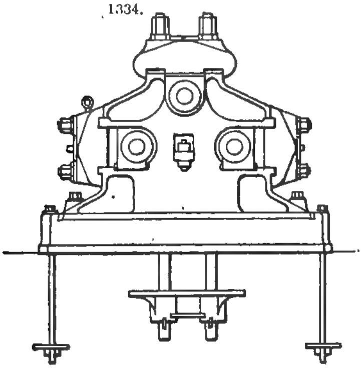
1333.



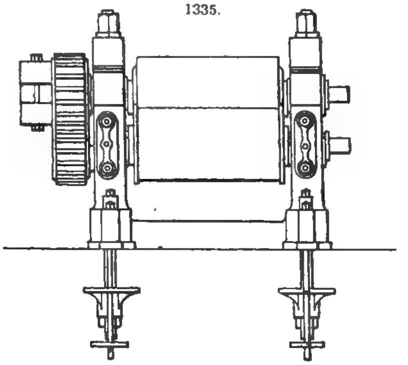
Figs. 1334 and 1335 show end and front views of the 3-roller mill made by Manlove, Alliott, Fryer, & Co., of Nottingham and Rouen. The bed and cheeks are entirely of cast iron, carefully proportioned to its work. Strong wrought-iron tie-bolts take the main tensional strains in the mill. The side roll-caps, while well established when the mill is working, are readily removable, and the rolls can be slid out without any lifting.

Cane-mills have been constructed with 4 and even 9 rolls. In the 4-roll mill, where 2 rolls are placed above and two below, the driving-power is said to be not much greater than that required for an ordinary 3-roll mill, while more juice is obtained; but this statement is very doubtful, and is negatived by the fact that 3-roll mills have quite superseded the 4-roll arrangement. In the 5-roll mill, 3 rolls are placed below, and 2 above; 10 per cent. more juice is said to be extracted by this plan, but much greater power is needed, and the begass is much broken up.

1334.



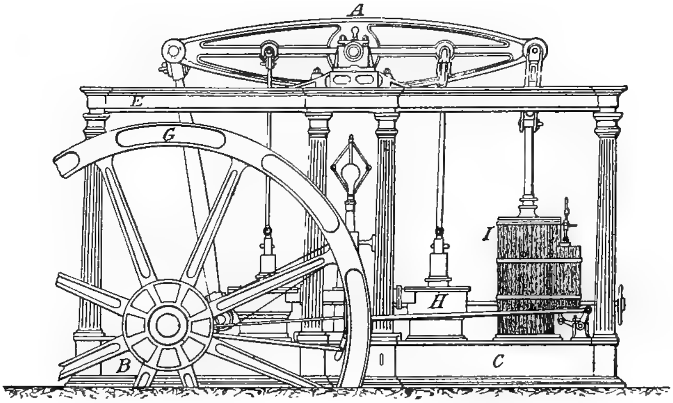
1335.

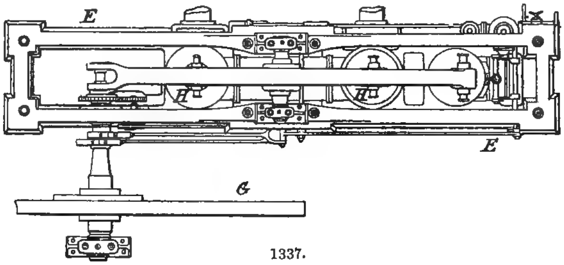


Motors.—With regard to the suitability of the several kinds of power for driving cane-mills, it has been ascertained, by comparing the results of 44 mills in Guadeloupe, that:—with windmills of inferior construction, the cane-mills extracted only 50 per cent. of juice; with ordinary windmills, 56·4 per cent.; with animal power, 58·5 per cent.; with water power, 59·3 per cent.; with steam power, 61·8 per cent.

Figs. 1336 and 1337 show an economical combination of a vertical beam-engine arranged so as to work two large air pumps, and with power enough to work the cane-mill at the same time. This style of engine is applicable when the sugar-factory is organized so as to run day and night, as all should to work profitably. The engine is constantly at work, and its exhaust-steam is as constantly absorbed by the juice. It is evident that by using one large engine instead of three (one each for the cane-mill, the triple-effect, and the strike-pans), much loss by friction and expense of attendance are saved. In the figure, E represents an entablature carrying the beam A, mounted by 8 columns on the bed-plate C; H are two large air-pumps in connection with the triple-effect and vacuum-pan; a massive fly-wheel G is necessary to secure regularity of motion.

1336.





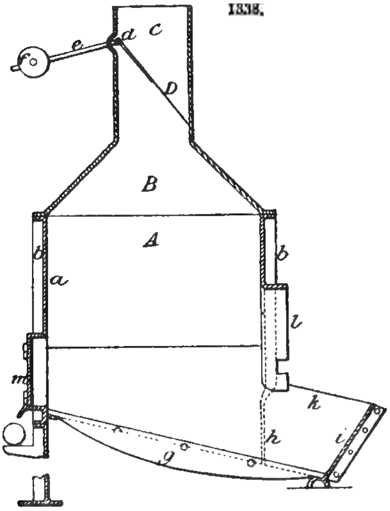
1337.

Fuels and Furnaces.—The use of coal and wood as fuel needs no remark. Whether wisely or not (see p. 1865), begass is largely employed for this purpose. Approximately, 2 lb. of begass equal 1 lb. of coal, or 16 lb. of begass to evaporate 1 gal. of water. So that the refuse of the canes should give fuel sufficient to make the sugar, when the canes are not completely exhausted of the saccharine juice. Ordinarily the begass requires preliminary drying by the sun and wind, but furnaces have lately been introduced for burning it in the wet state, as it leaves the mill.

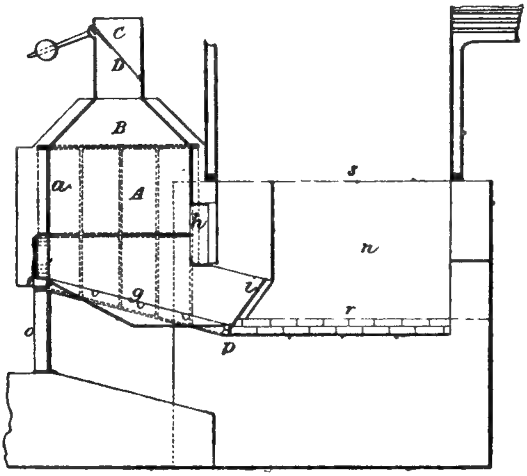
Marie's begass-furnace, made by Manlove & Co., is shown in Figs. 1338, 1339, respectively in section and as attached to a boiler fire-box. The chamber A is constructed of cast-iron plates *a* stiffened by ribs *b*, bolted together by flanges, and encased in brickwork. The pyramidal crown B is also of cast-iron plates, bolted upon A, and surmounted by the hopper C, in which the begass is dried, and through which it is fed to the furnace. An inclined balance-door D is placed in the hopper, working on pivots at *d*, supported in the sides of the hopper, one having a lever-arm *e*, upon which is an adjustable counterweight *f*, to regulate the quantity of begass admitted. The fire-bars *g* are inclined; their lower ends extend through an opening *h*, and are supported by an inclined bridge *i*, bolted to extensions *k* of the side walls of the furnace. The upper part of *h* is surrounded by a flange *l*, the dimensions of the flanged opening being varied as circumstances may require. The doors *m* give access to the furnace. The most exposed parts of the sides *a* are lined internally with fire-brick, and the walls *n* are similarly faced. The begass-furnace is shown supported at front on feet *o*, and at back upon a wrought-iron girder *p*, whose ends are built into the walls that support the fire-box *s* of the boiler. The lower part of the boiler fire-box is completely closed by brickwork *r*, supported on girders built into the side walls; the interval between the begass-furnace and the fire-box being also built up, the air to support combustion must come in through the fire-bars *g*.

Begass coming wet from the mill requires to be dried to render it fit for fuel, and it receives its preliminary drying in the external furnace. A coal fire having been first lighted in A, its walls become highly heated; the wet begass is then fed in through C, whose balance-door D gives passage to and spreads the begass uniformly upon the grate *g*, closing again immediately to re-establish the draft through the grate. In this arrangement, the heat which would go to evaporate the water, is stored up in the walls of the furnace, which quickly become hot enough to almost instantly dry the begass, and render it eminently fit for burning. As all the gases are compelled to pass through the mouth leading to the boiler-furnace *s*, perfect combustion is ensured, and there is little or none of the usual deposit in the boiler-tubes. The advantages of a furnace which will burn wet begass extend to the important gain represented by the avoidance of risk of fire, constantly to be feared when dried begass is stored in large quantity. The Marie furnace has been applied also to the "copper walls" for making muscovado sugar.

1338.

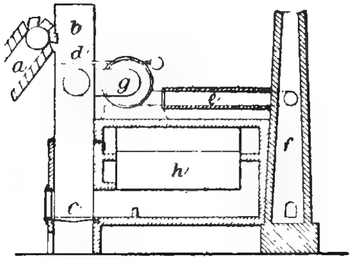


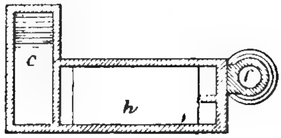
1339.



Norbert Rillieux, of Paris, also has a plan for drying the begass on its way to the furnace. His apparatus is shown in Figs. 1340, 1341. The wet begass is delivered by elevators *a* into the hopper *b*, leading at bottom into a chamber communicating with the furnace *c* of the steam-boiler *h*. In this hopper is a hinged horizontal flap *d*, on which the begass falls, and which is held by a balance-weight till the load accumulated upon it overbalances the weight, when the begass is discharged down the chamber, and passes into the furnace to be burnt, the flap being closed again by the balance-weight. While the begass is retained in the hopper, and descends through the chamber, it is subjected to currents of hot gases from the furnace, so as to become dry before passing into the fire. The hot currents may be accelerated by connecting the hopper by a pipe *e* with the chimney *f* of the boiler, the draught being regulated by a throttle-valve; and if required, a blowing-fan *g* may be provided in the pipe, and regulated so as to produce the required degree of desiccation.

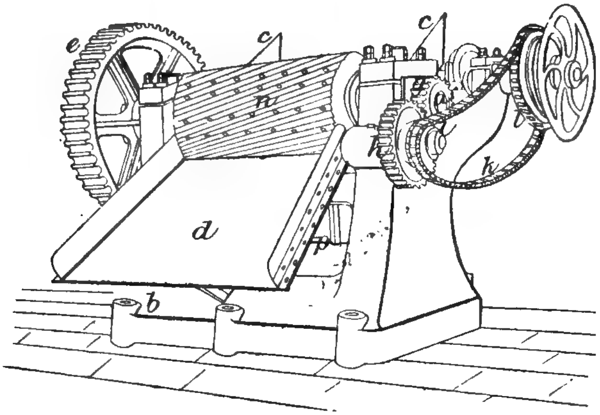
1340.





1341.

1342.

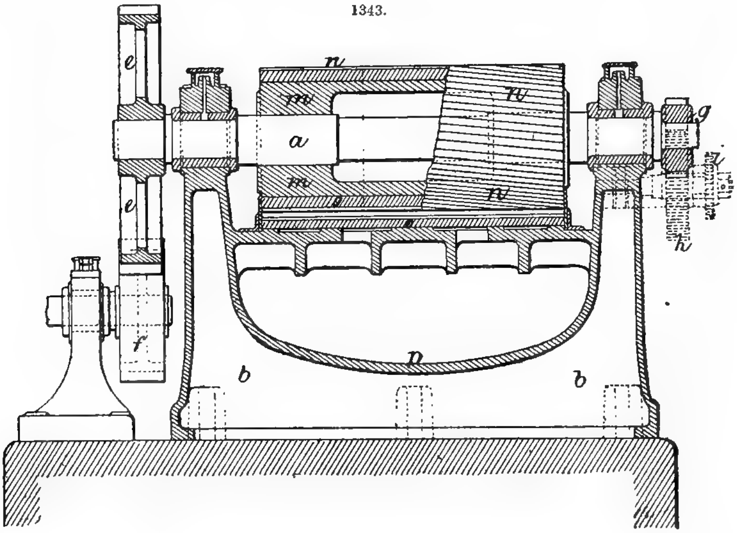


Disintegrating.—The imperfect liberation of the cane-juice by the crushing process of the ordinary mill has led to experiments in other directions. One result has been the invention of machines for effecting a more thorough mechanical disintegration of the cane-tissue. These may be conveniently considered under three sections:—(*a*) Defibrators, (*b*) Bessemer's press, and (*c*) Bonnefin's rasper.

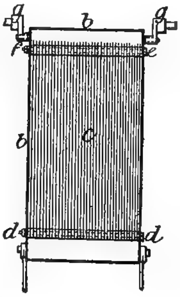
a. Defibrators.—This term (Fr. *défibreur*) is employed by several inventors. In Mignon et Rouart's, the cane is reduced to pulp, and by subsequent pressure, 77 per cent. of juice is said to be separated by the first crushing, and a further 25 per cent. on the weight of the begass by a second operation. The machinery is in operation in Guadeloupe.

Faure's defibrator, made by Manlove, Alliott, Fryer, & Co., is shown in perspective in Fig. 1342, and in horizontal section in Fig. 1343: *a* is a shaft carrying a cylinder, whose surface is provided with teeth running in a helical direction; *b*, a strong frame; an articulated cane-carrier receives its motion from the defibrator itself; *c*, inclined plane bringing the canes in front of the cylinder; *e* strong spur-wheel fixed to one end of the shaft *a*, and receiving motion by a pinion *f*; *g*, pinion fitted to the other end of the shaft *a*, and communicating movement to another spur-wheel *h*, in front of which is another toothed wheel *i* for a pitch-chain; *m*, drum of polygonal form keyed on to the shaft *a*, and to which are attached the toothed defibrating-plates *n*; *o*, a double counter-plate, formed of two distinct parts: the front part is on the feed side, where the opening is wider, and its teeth project in the same direction as those of the drum, although inclined inversely, their object being to rectify the position of canes which are presented endwise; the back or working counter-plate at the outlet side has teeth which project in the opposite direction, and effects the defibration of the canes, which it arrests and rolls on, crushing them under the teeth of the drum. The small quantity of resulting juice passes through little holes in the counter-plates, into the channel *p*, whence it is conducted to the juice expressed by the cane-mill. The canes are fed by hand or by the carrier broadside-on upon the inclined plane which conveys them in front of the defibrator. The object of the machine is to prepare the cane for the ordinary cane-mill, by breaking up the fibres and knots lengthwise. It is stated that by its use the yield of juice has been increased from 70–71 to 78–82 per cent.

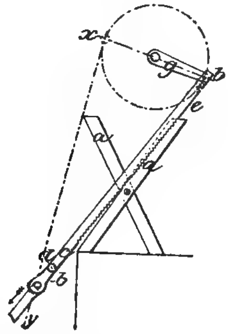
1343.



1345.



1344.



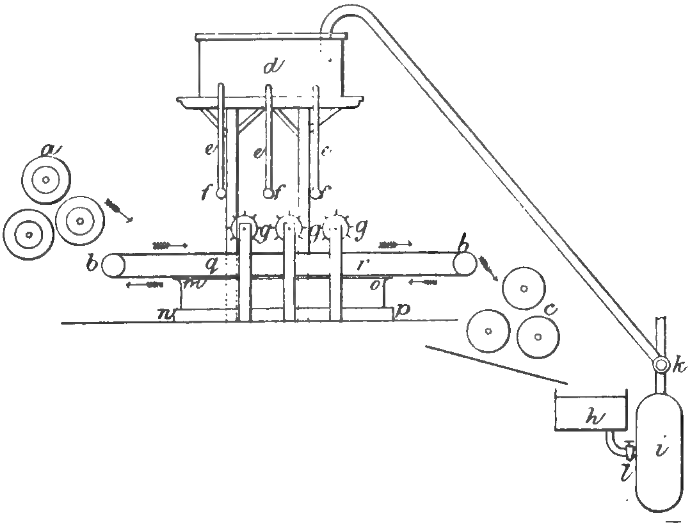
b. Bessemer's press.—An account of the cane-squeezing machine invented by H. Bessemer in 1849–52 is not necessary, as many such accounts already exist, and the machine never came into general use. The machine consisted of plungers working in cylinders, across whose path the canes were passed endwise, and were thus crushed section by section. When applied to freshly-cut canes in the W. Indies, the results fell short of the ordinary 3-roller cane-mill.

c. Bonnefin's rasper.—Fig. 1344 shows a side view of the apparatus, and Fig. 1345 a back view of the frame of saws. *a* is the rack in which is placed the bundle of canes to be cut; *b*, a frame carrying a number of parallel saws *c*. The lower end of each saw has a rod *d* passed through it, and the saws are kept apart by distance-pieces slipped on to the rod and interposed. The upper ends of the saws hook over a rod *e*, and are similarly kept apart; they are clamped and held by the screw-nut *f* screwing on to the end of the rod. The lower end of the saw-frame is jointed to rods, free to move to and fro in guides in the direction of the arrow. The upper end is jointed to a crank *g*, to which a revolving motion is given. The saws will thus alternately move through the cradle, cut through any canes placed in it, and move back into the position shown by the dotted line *x–y*, so as to be ready to act upon a fresh bundle of canes. When the cane has been rasped to shreds, it is reduced to pulp by disintegrating apparatus, and then the juice is separated by pressure. The predecessors of this plan were Manfold's sawdust method and Murdoch's system of cutting obliquely and disintegrating.

Maceration.—It has been sought to facilitate the extraction of the juice by submitting the cane to the action of water or steam, either before the crushing operation in the roller mill, or at an intermediate stage between two such crushings. It seems to be undecided whether the saturation or the extra crushing should be credited with the increased yield of juice. Probably both assist; but it has been stated that the return of juice is raised from 60 per cent. to 75 per cent. by previously slicing the canes longitudinally, without any application of water or steam.

Several methods have been devised for carrying out the saturating process on a practical scale, known as "maceration" or "imbibition" processes. The most important of these is Duchassaing's, shown in Fig. 1316. The mill *a* receives the canes and crushes them, giving 68 per cent. of juice. The begass falls upon an endless cloth *b*, which conducts it to a second mill *c*; *d* is a tank containing boiling water; *e* are tubes terminating in pipes *f* parallel to the endless cloth, which sprinkle water from the tank *d* upon the begass passing from the first to the second mill; *g* are beaters which turn the begass and thus equalize the imbibition; *h* is a tank which receives the juice from the mill *c*; *i* is a *monte-jus* which sends this juice, if its density is not sufficiently great, into the tank *d*, to serve for a second maceration of new begass, or, if it is dense enough, by the joint *k* to the defecation. The endless cloth *b* dips so that the portion between *q r* immerses the begass in boiling water contained in the vessel *m n o p*, thus increasing the maceration. Since the apparatus has come into extensive use, it has been simplified by dispensing with the beaters *g* and the vessel *m n o p*. The system raises the yield of sugar from 9·40 per cent. on the cane to 11·04 per cent.; it received an award of 4000*l.* from the General Council of Guadeloupe in 1876.

1316.

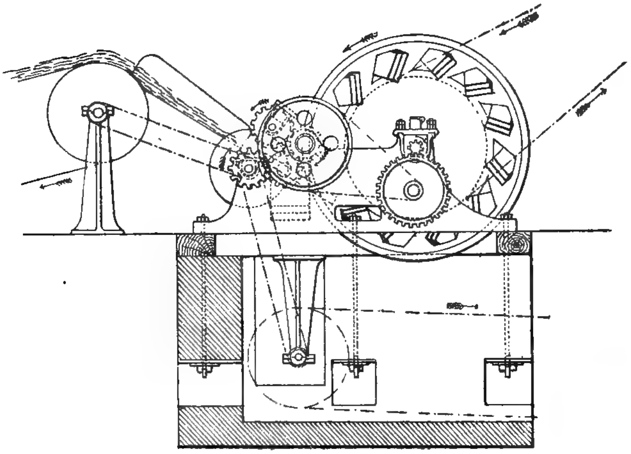


It may be mentioned on the authority of Col. Thomas P. May, the well-known American author, who was formerly a large sugar-planter in Louisiana, that auxiliary mills (double crushing) have given highly satisfactory results in Louisiana during the season just ended (1881–2). These mills are being erected by Leeds & Co., for over 50 years the largest makers of sugar-machinery in that state. Five rolls are the number adopted by this firm, and, on the Poydras plantation, one of these mills yielded the unusual result of 126 lb. of sugar from 1 ton (2000 lb.) of canes.

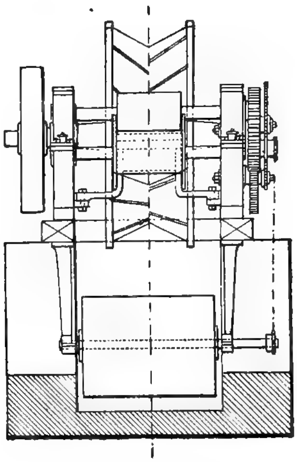
Diffusion.—All the processes hitherto described for extracting the juice from the cane have depended for success upon the more or less complete *rupture* of the juice-containing cells. "Diffusion" differs from them essentially, in dispensing with the breaking up of the cells, and the machinery required therefor. The chief development of the diffusion process has been in the beet-sugar industry (see pp. 1842–6), but several methods of applying it to cane have been introduced. The cane is even said to possess an advantage over beet with regard to diffusion, in that the nitrogenous matters are so placed in the secondary cells that water at a high temperature can be used without injuring the membrane.

Slicing-machines.—The first operation is to reduce the cane to diagonal slices 3–4 in. long, and $\frac{1}{16}$ in. thick. One of the most successful machines for this purpose is that made by A. Jouin et Cie., Paris, extensively used in Guadeloupe, and shown in Figs. 1347–1350. It consists of a disc, the periphery of which, formed like a truncated cone, either simple or double, is armed with a series of blades, whose inclination with that of the periphery is such that the sliced matters are driven by centrifugal force away from the wheel. A pair of feed-rollers, placed in front of the disc, pass forward the canes to be cut, at a speed proportioned to the capacity of the machine, and the thickness of slice desired. The apparatus is supported on a foundation-plate, fixed to the ground or the floor of the works. A suitable cover surrounds the machine, to prevent the slices being scattered, and make them fall into the pit below, whence they can be withdrawn in any convenient manner. An endless feed-apron conducts the canes to the machine, as in ordinary roller-mills.

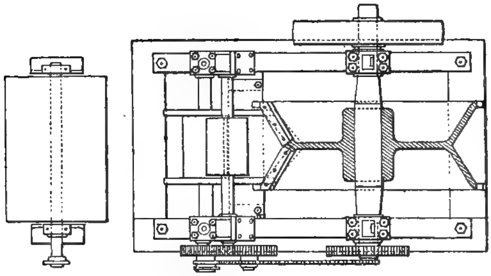
1347.



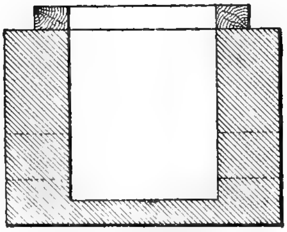
1348.



Scale $\frac{1}{50}$



1349.

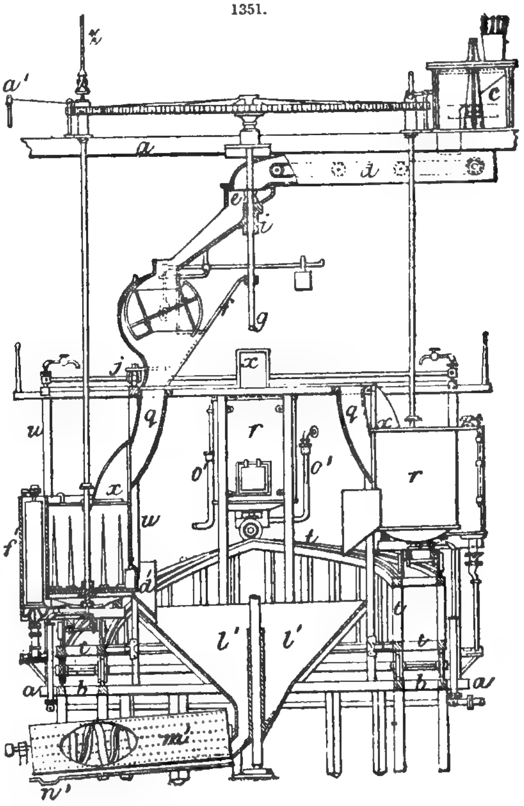


1350.

Bouscaren's System.—This system, introduced into Guadeloupe by L. F. G. Bouscaren, is shown in Figs. 1351–2. The cane as sliced at *c* is conducted in measured quantities to each in succession of a circuit of 12 open diffusors *r*, consecutively subjected to elevation and depression, so as to cause the liquor to flow by gravity from one to the other. Each has a steam-chamber for heating its liquor, that the albuminous impurities in the cane may be coagulated before they mingle with the sugar. Elevation and depression are obtained by supporting the circuit upon an annular double inclined track *b*, slowly and continuously rotated, each diffusor being held by vertical guides *n*.

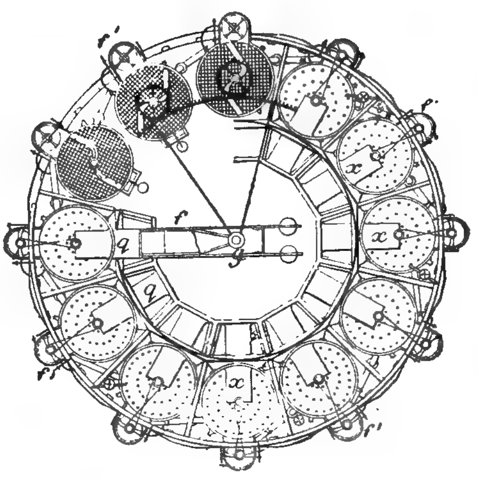
The bottom of each is kept in constant communication with the top of the one next below, by means of an extensible pipe. The apparatus is provided with means of agitating the contents; a series of straining-diaphragms and devices for keeping their meshes open, so as to retain suspended impurities without interrupting the flow of liquor; and mechanism for discharging the spent contents and cleansing the vessel, without interrupting the operation, and for straining and delivering the solid refuse.

1351.



At Monrepos, Guadeloupe, with an apparatus consisting of 6 diffusors, juice having a density nearly equal to that of the natural juice is obtained, 1½ hour being sufficient for extracting the sugar. The yield of white sugar amounts to 12½–13 per cent. of the weight of the cane.

Robert's System.—Julius Robert's process, sufficiently familiar to those engaged in the beet-sugar industry (see pp. 1843–4), is coming into use among cane-planters. The machinery required comprises a 45-H.P. steam-engine, cane-cutters, diffusion-vessels, and a heater. The cane-cutters are constructed by Franz Rebicek, of Vienna; they make about 225 rev. a minute, effect a clean sharp cut, elliptical in shape, 3–4 in. long, and $\frac{1}{8}$–$\frac{1}{16}$ in. thick, and slice up a minimum average of 6000 lb. an hour. The elliptical cut severs the maximum number of central cells, wherein the sugar is said to chiefly reside. The diffusion-vessels are of light boiler-iron with cast-iron bottoms. They measure 120 cub. ft., and contain about 4200 lb. of cane-chips and 3250 lb. of water, 10 forming a battery. Each vessel has 5 pipes—for water, to send juice to the heater, to receive juice from the heater, to discharge juice into the clarifiers, and to pass juice from one vessel to another, besides one direct from the boiler for steaming purposes, and one for discharging the water from the vessel before emptying the exhausted chips. The vessels have a manhole at top for receiving the chips, and another 4 ft. sq. next the bottom for discharging the exhausted chips. The concentrated juice is drawn from the vessel through a perforated false bottom. The heater, of boiler-iron, and in direct communication with the steam-boiler, is used for heating the juice on its passage from one diffusor to another, as it traverses a system of copper pipes completely surrounded by steam.



1352.

Hydrostatic pressure is used in passing juice from one vessel to another, through the heater, and into the sugar-house; this is obtained by a water-tank of 1500 gal. capacity, placed about 20 ft. above the diffusors. As soon as vessel No. 1 is filled with chips, and while No. 2 is being filled, direct steam is let in until it begins to escape at the top. Steam is then shut off, and water is let through the heater until the vessel is full, when the manhole is closed. No. 2 being filled with chips and duly steamed, water is again let down from the tank through the heater into No. 1, driving the liquid into No. 2 through the connecting-pipe. No. 3 is filled, steamed, and charged with juice through No. 2, in the same way. When No. 4 is filled with chips, cold water is let directly from the tank into No. 1, driving the juice which was in it through the heater into No. 2, and from 2 to 3 and 3 to 4. Next, cold water is run into No. 1, and from No. 1 to No. 2, from No. 2 through the heater into No. 3, then directly into 4 and 5, and so on, care being taken to preserve the temperature of the last vessels filled at about 88°–93° (190°–200° F.). When the hot juice has passed through No. 7, it is sufficiently concentrated, and is discharged into the sugar-house; No. 1 is now emptied, and No. 2 becomes the first vessel in the battery, and the work goes on as before, there being always 7 vessels working, one emptying and two refilling: so that practically, when the work is in full operation, as fast as one vessel is filled, a charge of concentrated juice goes into the sugar-house, and one vessel with exhausted chips is emptied. The exhausted chips are discharged through the large manhole near the bottom of the diffusor, and received on a carrier which drops them into the begass carts. A vessel is emptied by two men in 6–8 minutes, including opening and closing the manholes; filling requires 12–15 minutes.

The normal condition of the battery in regular working order is:—

No. of Vessel.	Temperature of Juice.	Specific Gravity.	Saccharometer at 63½° F.	Baumé at 63½° F.	Remarks.
I.	21° (70° F.)	1·00030	0·08	0·048	These figures correspond to cane-juice of 7¾° B.
II.	29° (85° F.)	1·00310	0·80	0·44	
III.	32° (90° F.)	1·00544	1·40	0·80	
IV.	49° (120° F.)	1·01134	2·90	1·6	
V.	93° (200° F.)	1·01618	4·12	2·3	
VI.	87° (189° F.)	1·02537	6·45	3·6	
VII.	91° (196° F.)	1·04599	11·40	6·3	

The density of diffusion-juice in practical working is 1°–1½° B. less than that of the raw juice, which gives an excess of water to be evaporated amounting to 16–20 per cent.; this entails an additional expense of about 8½*d.* on every 1000 lb. of cane, estimating wood at 12*s.* 6*d.* a cord (8 ft. × 4 ft. × 4 ft., about ½ ton), and coal at 3*s.* 1½*d.* a bar. (200 lb.).

The comparative characters of mill- and diffusion-juice are stated thus:—

Mill-Juice.		Diffusion-Juice.
1·05746	Specific gravity	1·04620
11·80 per cent.	Crystallizable sugar	9·65 per cent.
1·68 ,,	Uncrystallizable ,,	1·38 ,,
0·62 ,,	Foreign substances	0·42 ,,
14·10	Saccharometer	11·45

Diffusion ordinarily extracts nearly 83 per cent. of the juice, leaving 17 per cent. in the chips and refuse water. More can be obtained by continuing the process, but there is a point beyond which it does not pay to go, because, by drawing off more, less cane is worked up, and the greater amount of fuel required to evaporate the extra water is not paid for by the additional sugar. The 83 per cent. of juice sent to the clarifiers gives:—

Crystallizable sugar	8·81 per cent.	on the weight of the cane.
Uncrystallizable ,,	1·25 ,,	
Foreign substances	0·46 ,,	

The loss by clarification, skimmings, and sediments amounts to about 6 per cent. on the juice, or 4·98 on the cane; therefore the juice really obtained in green sugar is 78 per cent. of that present in the cane. Of this,—

8·28 per cent. is crystallizable sugar.
1·17 ,, ,, uncrystallizable ,,
0·43 ,, ,, foreign substances.

A week's run of the process in Louisiana, working up 987,945 lb. of cane, gave:—

Density of Mill-Juice.	Density of Diffusion-Juice.	Yield of undiluted Juice on the Weight of Cane.	Sugar Obtained.					Molasses Obtained.			Total Sugar and Molasses in lb.	Percentage of	
			In hhds.		In lb.		Total in lb.	Barrels.	Gallons.	Lb.		Sugar	Molasses
Saccharo-meter.			1st Product.	2nd Product.	1st Product.	2nd Product.						on Weight of Cane.	
14·10	11·45	82·92	29	14·5	35595	16111	51706	100	4249	50778	102,484	5·234	5·193

The water required to work the diffusion apparatus is about one ton to every ton of cane; it is important to have pure water, as it has a great influence on the quality of the juice. Water containing organic impurities in partial decomposition would add to the juice similar elements of fermentation to those which the process aims at leaving in the cells of the cane. About 6–7 per cent. of the water is saved, if, instead of emptying the water from the vessel containing exhausted chips, it is forced into the next. A peculiar difference exists between mill-juice and diffusion-juice, in that the latter requires longer to crystallize when brought to syrup. Besides this, by the continued application of high temperature, part of the crystallizable sugar is inverted, as proved by the excess of molasses. In the matter of rapidity of crystallization, diffusion-juice apparently labours under a disadvantage as compared with mill-juice; but this is obviated by supplying more receivers for the syrups, and by heating the "cooling-room." The begass forms an excellent material for paper-making. The chief drawback to diffusion is the large quantity of water required, which, though much of it can be utilized for condensing purposes, represents a proportionate extra evaporation and extra cistern space; but under favourable circumstances, the larger yield of sugar more than compensates for the extra cost.

The Robert process is in use at the Aska works, Ganjam, Madras, where the sugars made by it analyze:—

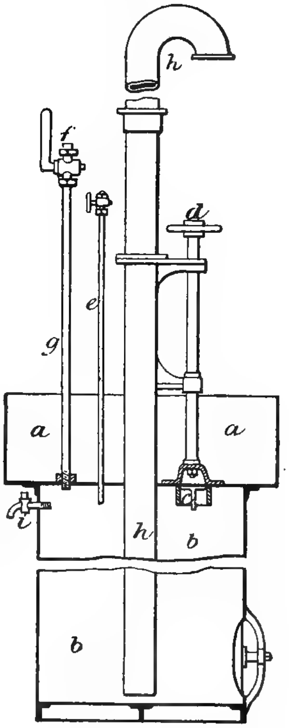
	From Uncharcoaled Juice.				From Charcoaled Juice. Using a dense char of 62 lb. per cub. ft., in proportion of about 0·6 times the weight of dry sugar obtained.		
	Masse-cuite.	Aska.	B.	◇B	*Masse-cuite.*	◇B	◇A
Sugar, crystallizable ..	76·000	95·500	99·500	99·600	80·000	99·500	99·100
„ uncrystallizable	12·740	2·650	0·230	0·240	11·920	0·210	0·470
Ash	1·507	0·306	0·103	0·036	1·917	0·067	0·072
Water	5·110	1·000	0·150	0·100	5·290	0·035	0·080
Unknown	4·643	0·544	0·017	0·024	0·873	0·188	0·278
	100·000	100·000	100·000	100·000	100·000	100·000	100·000

Aska is *masse-cuite* simply spun; B and ◇B are made by washing the Aska in the centrifugals with about ¼ gal. of water to 160 lb., and are marked according to grain and colour; ◇A is of 1877 manufacture, and hence the comparatively large quantity of uncrystallizable sugar, produced by damp and heat during the long storage.

The system has been quite abandoned in Louisiana, after prolonged trial.

Pumps and Monte-jus.—As the apparatus by which the juice is extracted from the cane is generally situated on the ground floors of the building where the operations are conducted, it becomes necessary to adopt means for raising the juice into the vessels where it is to undergo purification and concentration. This is not the case in Louisiana, where the mill is usually placed at sufficient height to permit the juice to descend by its own gravity throughout the operations. Force-pumps, worked from the mill, possess many disadvantages, including limited capacity, churning of the liquid and consequent admixture of air, and contamination of the liquid with the grease used in their lubrication. They soon gave place to the *monte-jus* ("juice-raiser"), copied from the French. This is made in many different forms, one of which is shown in Fig. 1353. Its body consists of two chambers *a b*, separated by a steam-tight diaphragm; the upper chamber *a* receives the juice to be elevated while the charge in the lower chamber *b* is in course of elevation. When

1353.



the lower chamber *b* is empty, the valve *c* is raised by turning the handle *d*, while the tap of the air-pipe *e* is opened. The juice contained in the upper chamber *a* immediately descends through the valve *c*, any air that may have been imprisoned in the chamber *b* escaping through the air-pipe *e*. This air-pipe extends about 6 in. into the lower chamber *b*, for the purpose of ascertaining when the chamber is sufficiently full, the escape of air through the pipe *e* being stopped as soon as the juice reaches its lower end. The cessation of the whistling noise made by the air rushing through the end of this pipe *e* constitutes the signal for screwing down the valve *c*, to prevent any further flow of juice into the lower chamber *b*. The air-tap is then closed, and the steam-tap *f* of the steam-pipe *g*, communicating with the boilers, is opened, when the empty space between the surface of the juice and the top of the lower chamber *b* fills with steam, which drives the juice out through the discharge-pipe *h*. As this pipe is carried down to within a short distance of the bottom of the *monte-jus*, nearly the whole of the contained liquor is forced out of the lower chamber *b*. As soon as any indications of steam appear at the mouth of the discharge-pipe, the steam-tap *f* is shut, and the valve *c* and air-tap *e* are opened to let in a fresh charge. It will thus be seen that the action of the *monte-jus* is exceedingly simple, only one precaution being necessary, viz. to shut the valve *c*, through which the juice is running, in time. If the juice be allowed to reach the top plate of the chamber *b*, the steam, when let in through the pipe *g*, will mix with and boil the juice, but will not elevate it; considerable difficulty and delay sometimes arise from this circumstance. As a precaution against carelessness, an overflow-tap *i* should be fitted to the shell of *b*, a few inches below the top, so that the superabundant juice might be drawn off. The juice, as it comes from the *monte-jus*, is sufficiently warmed to retard fermentation on its way to the clarifiers.

While this instrument remains by far the most generally adopted means of raising juice, it has been objected that its interior is not readily accessible, and that it is therefore difficult to keep clean, whereby fermentation may be caused in the juice. It is also urged that the liquor is diluted by the admixture of condensed steam. Hence, in many cases, the *monte-jus* has been replaced by centrifugal pumps. In favour of these, it is advanced that there are no valves nor other mechanism to become a refuge for dirt, no air nor steam is forced into the liquor, and, with properly adjusted arms, the juice is raised in a solid column without churning. Many statements, however, point to the fact that the churning is often seriously worse than with the *monte-jus*. In the best central factories, steam in the *monte-jus* is replaced by air under a pressure of 60 lb. a sq. in., thus obviating most of its drawbacks.

Defecation and Clarification.—Having, by any of the methods described, extracted as much as possible of the juice from the cane, the next operation is to eliminate from that juice all matters regarded as impurities from the sugar-maker's point of view, i. e. everything except the sugar and the water holding it in solution.

Preliminary Straining.—First of all, unless the juice has been extracted by diffusion, it is necessary to remove the gross impurities derived from the breaking-up of the canes. This may be done by a series of strainers, arranged so as to be easily removed, cleaned, and replaced. One of the best contrivances is a modification of the endless wire-web strainer, not essentially different from that on which the rag-pulp of paper-works is agitated and filtered from a great part of its water. The wire-gauze in common use has 40–60 threads per in., but it can be obtained of 80–90: the finer the better, provided the web presents a clean surface as fast as necessary. The strained juice is received in a shallow tray placed immediately under the horizontal part of the straining web, and passes thence by a gutter to the clarifier.

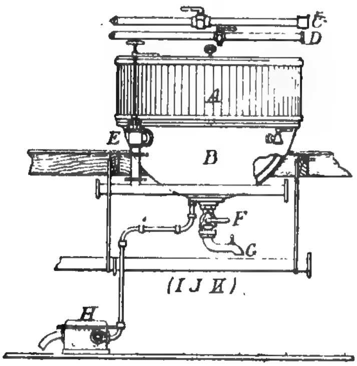
The chief means introduced for cleansing the juice are heat, chemicals, and filtration.

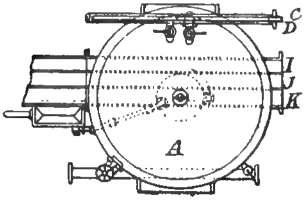
Heat.—Heat alone will exercise beneficial effect both by checking acidity—scalding the juice prevents acetous fermentation setting in, probably by destroying the fungoid germs which are its necessary accompaniment (presumably its cause); and by evaporating a portion of the acids holding the albuminous matters in solution, whereby the albumen is coagulated and rendered insoluble. It is also a valuable aid to the action of chemicals upon the juice, increasing the energy of the reactions set up, and thus greatly reducing the duration of the operation. Hence heat is now universally availed of in recognized processes of defecation and clarification. But if the heat is applied injudiciously, much of the crystallizable sugar is inverted.

Steam Defecators and Clarifiers.—As the degree of heat employed is a matter of vital importance, it is most conveniently applied in the form of steam, that being readily controlled. Figs. 1354 and 1355 represent respectively an elevation and plan of a steam defecator made by Fawcett, Preston, & Co., Liverpool. The part B is composed of a copper, spherically-shaped lining, mounted in a cast-iron casing, to which high-pressure steam is admitted. The upper part A is a light curb of copper or iron to give capacity, and is clothed with lagging to prevent escape of heat. C D are pipes for juice and water; E is the steam-cock; F, the cock for drawing off the defecated contents; and G, a swivel-mouth pipe to direct the contents of the defecator as required into the clear-juice gutter, the turbid-juice gutter, and the washings-gutter. As the steam condenses in the double bottom of the defecator, the water flows away through the condense-water box H.

Lately many planters have adopted another system of defecating. Instead of providing 4, 8, or 12 separate defecators, with corresponding equipment of double bottoms, cocks, and pipes, they establish a powerful juice-heater, or vessel full of tubes fixed between two tube-plates. The steam is outside the tubes, and the juice from the mill traverses the space inside the tubes. If the mill gives 1500 gal. of juice per hour, a heater with 300 sq. ft. of surface will deliver the whole into say 3 empty tanks of 500 gal. each; there the juice is defecated and left to subside. By using a juice-heater and 3 tanks, the same result is obtained as by a costly steam-boiler working at high pressure and 4 very costly defecators with their mountings.

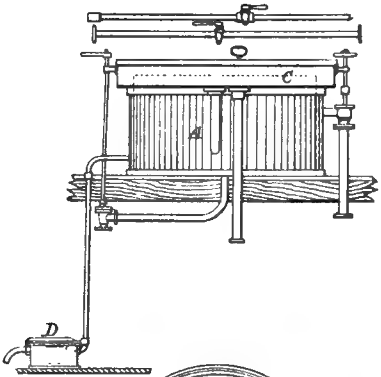
1354.

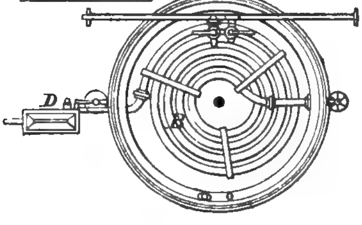




1355.

1356.





1357.

Figs. 1356 and 1357 represent elevation and plan of a steam clarifier and evaporator, made by Fawcett, Preston, & Co., Liverpool, which is used for treating the syrup after it leaves the triple-effect (see p. 1895). It is a cylindrical vessel provided with a steam-worm B fitted in the lower part; at the upper part, a border and gutter is formed, into which the scum is brushed as it rises on the syrup. The condensed steam in the shape of hot water passes through the box D, which has a float and cock to prevent uncondensed steam from passing uselessly away. The exterior A is lagged to economize steam by preventing the syrup from cooling. Every means must be adopted to save heat and fuel in a sugar factory, as it may be stated generally that 240 H.P. of steam are required to make a ton of sugar per hour, or 20 H.P. per hour for 12 hours; and in many sugar-producing countries, coal at the furnace-mouth costs 3*l.* a ton.

The use of the clarifier may be described in general terms as follows. The juice is raised to a temperature of 80° (176° F.), and sufficient milk of lime is added to neutralize the acid in the juice. The heat is then continued till a scum of impurities has risen to the surface, and commences to crack. The time occupied in this should be about 10–12 minutes from the commencement of the operation. The steam is then shut off, and the liquor is allowed to subside for 15–20 minutes, when the scum remains at the top; some heavy matter will have fallen to the bottom, and between them will be the clarified cane-juice, clear and of a pale straw-colour. The clarification being complete, the two-way cock is first turned on to the smaller aperture, until the top scum begins to appear; the cock is then turned to the large way, and the plug is taken out. The bottom sediment and top scum are conveyed to a cistern, whence they are placed in bags, and any juice remaining in is squeezed out, leaving only a small portion of solid matter behind.

Chemicals.—Of these, the most important and most widely used is slaked lime; following it come bisulphite of lime, sulphurous acid, lead acetate, and sundry special compounds, as well as antiseptics.

Lime.—The effects of heating are greatly augmented by the simultaneous application of a strong alkaline earth, such as lime, which combines with the liberated acids, and with any carbonates present, and thus forms an insoluble precipitate, which carries down much of the impurities. But any excess of lime beyond what is required to neutralize these acids will re-dissolve the coagulated albumen, and preserve it in a state of solution, until the excess of lime is again neutralized by addition of acid. The operation, which is called "tempering," is thus obviously one of extreme delicacy. The first point to ascertain is the exact amount of lime required by a given quantity of cane-juices. A bottle containing exactly 250 septems ($\frac{1}{40}$ gal.) is filled with filtered cane-juice of known sp. gr., and the juice is transferred to a beaker over a spirit-lamp, and stirred occasionally with a glass rod till it boils; after boiling for about a minute, clear saturated lime-water is poured in, a few drops at a time, till the juice shows a neutral reaction. The beaker is then taken off the lamp, and its contents are allowed to settle for a minute. If a coagulum of large flakes floats about in the transparent slightly-coloured liquid, and readily separates and subsides, the points of neutrality and of proper clarification coincide. The exact number of septems of lime-water used is then noted. If the floccules are small, and do not readily separate, the juice if boiled would throw up scum, and is not properly clarified. More lime-water is added till the indications of proper clarification are attained. The juice will now have a deeper tint than if excess of lime had not been required. The total number of septems of lime-water being noted, the calculation as to how much quick-lime is required for a given number of gallons of juice is:—If 250 septems of cane-juice required 20 septems of lime-water to render it neutral, and 10 more for clarification, then $30 \times 40 = 1200$, the number of septems of lime-water that 1 gal. of juice would have taken; saturated lime-water at the temperature common in tropical boiling-houses contains 0·00862618 gr. of quick-lime, therefore $1200 \times 0{\cdot}00862618 = 10{\cdot}351416$ gr. of quick-lime required by 1 gal. of juice. As a rough rule, the proportion of 1 septem of lime-water to 250 septems of cane-juice is nearly equal to 1¼ dr. of quick-lime to 100 gal. of juice. Hence the number of the test, multiplied by 1¼ dr. gives the weight in dr. of quick-lime required for 100 gal. of juice. This result is 1 per cent. too little. The test should be frequently repeated.

In the test, saturated lime-water is used, because it is easy to have it of uniform strength; but on the large scale, to use lime-water would entail great dilution of the juice, and waste of fuel in the subsequent evaporation. Hence "milk" or "cream" of lime is resorted to. The lime used must be thoroughly burned, quickly slaked with clean water (enough water being used to impart a creamy consistence), and carefully filtered through a very fine wire sieve, to remove all fragments of flint and unburnt and unslaked lime. The weight of these impurities removed must be deducted from the amount of quick-lime originally taken. Quick-lime can only be kept in perfect condition in closed vessels. The juice being tested as to its density and acidity, and the milk of lime being prepared, the twin process of defecation and clarification commences.

There are several ways of carrying it into operation. One of the most simple is that known as "cracking." It necessitates the use of two or more clarifiers, and is conducted as follows. The strained juice is admitted into the clarifier till sufficient has accumulated to prevent injury by heat. Fire is then made under the clarifier (or steam is admitted into the jacket or coil), and by the time it is full of liquor, the temperature will have risen to about 54° (130° F.). The "temper-lime" is then thoroughly incorporated, and the heating continued. A thick greenish-yellow scum appears on the surface, and increases in thickness, changing colour from exposure to the air; at about 79°–82° (174°–180° F.), numerous minute air-bubbles form a frothy layer under the thick scum, by and by forcing their way at a few points through the scum, which soon cracks, and shows the bubbles. The heat is then quickly withdrawn, and the contents of the clarifier are allowed to rest for 15–30 minutes or more. Ebullition is avoided, because it would break up the floating scum and diffuse it through the mass. The time allowed for settling depends on the nature of the juice and the proper apportioning of the lime. After settling, there is a layer of coagulum at top, and a precipitate at bottom, while the body of the liquor is bright and transparent, with a more or less deep sherry-tint, and minute flakes floating thick in it. If it is hazy, the heat has not been enough to clarify, or the lime has not been sufficient. After standing, the clear liquor is run off into the filter, and thence to the evaporating apparatus; the scum and sediment, with the considerable quantity of juice that invariably accompanies them, are usually run off to the skimmings-cistern, to be used in setting up liquor for rum (see p. 228).

When the clarifier has a steam-coil or -jacket, little loss of time occurs, for as soon as enough liquor is in the clarifier, steam is turned on so as to attain the desired temperature by the time the vessel is full. Fire-clarifiers are discharged by a stopcock near the bottom, till the liquor begins to run muddy; steam-clarifiers, by a valve in connection with a tube that rises 4–6 in. above the bottom, so as not to disturb the sediment.

This method is open to the objections that:—(1) Clarification is rarely attainable below the boiling-point of the juice, consequently the juice wants brilliancy and transparency, and minute floating particles render the filtration unsatisfactory; (2) the floating matter is thrown up as scum during the concentration, causing waste of juice in the skimmings.

Dr. Shier's modification is as follows:—The strained juice is boiled briskly for 5 minutes, the scum being constantly beaten down. While boiling, the proper quantity of temper-lime is added mixed with clay-batter, gypsum, or whiting-batter; the boiling, stirring, and beating down are continued for a few minutes. Neutralization being effected, the whole contents are rapidly withdrawn into a subsider, and left till the coagulated flocculent matter has subsided. The clear juice is drawn off and passed through a filter into a cistern. Here, excess of lime is corrected by careful addition of dilute sulphuric acid. It is safest to cease adding acid when the alkaline reaction becomes extremely feeble. Were the lime in excess, the sugar would be dark-coloured; were the acid in excess, the grain would be fine and soft, and part of the sugar would become uncrystallizable. The addition of heavy matter to the temper-lime causes the impurities to form a sediment which may be filtered off, instead of a scum which needs skimming. It is said to effect a great saving of juice. Clay-batter is prepared from stiff clay (containing as little sand and organic matter as possible), well dried, crushed to powder, and screened through a wire-gauze sieve of 10–14 threads per in. The sifted clay is mixed up with clean water to the consistency of cream or batter. About 4–8 gal. of this batter, mixed with the cream of lime, go to 500 gal. juice. Gypsum or whiting used in place of the clay must be in very fine powder.

Howard's process, strongly recommended by Wray, is as follows:—The juice is strained and gently warmed; for each 100 gal. of juice, 2 oz. of finely-sifted quick-lime, made into a cream with water, are added; the whole is well stirred, and heated to 82° (180° F.), until a thick crust forms on the surface, and shows a disposition to crack. This occupies 15–20 minutes after the addition of the lime; if it is very slow, the heat may be raised to 93° (200° F.), but not beyond. When the crust shows signs of cracking, the fire is stopped; the liquor is allowed to rest for 10 minutes, and drawn off through a fine strainer into a "precipitator." Here the firing is urged as high as possible without actual boiling, the rising scum being constantly skimmed off. The liquor is then boiled, continuing the skimming for 10–15 minutes, after which, the "finings" are well stirred in, and the boiling is prolonged for another 2–3 minutes, when the whole is thoroughly agitated, quickly run off into a subsiding-tank, and allowed to rest for 2–6 hours before passing through charcoal-filters into the evaporators.

The "finings" are thus prepared. Well-burnt lime is slaked with boiling water so as to form a cream; an equal bulk of water is added, and the mixture is boiled for some minutes, until the lime assumes the appearance of fine curd; the extraneous matter is then washed away, and the lime and liquor are run through a fine sieve. About 2½ lb. of alum for every cwt. of solid sugar (say 100 gal. of cane-liquor) is dissolved in 6 gal. of water, adding about 3 oz. of whiting (purified chalk) for each 2½ lb. of alum, the mixture being stirred until effervescence ceases. It is allowed to subside, and the solution (containing sulphate of potash, which is very injurious to sugar) is drawn off from the precipitated matters (alumina and sulphate of lime). After this, the precipitate is well shaken up with the prepared lime-curds, which are in such proportion that turmeric-paper barely changes colour by immersion in it, and recovers its yellowness when dry. The finings settle to the bottom of the vessels, and, after draining off the supernatant liquor, are placed on blanket-filters, until the mass contracts, and cracks on its surface; the finings are then fit for use. Cane-liquor is added in such proportion as will bring it to a creamy state, and then the whole is mixed equally into the liquor to be fined. The clarified cane-liquor remains for several hours before the bright liquor is drawn off. The object of the process is to procure sulphate of alumina free from potash and ammonia (see Alumina, p. 333). The alumina greatly assists the purifying action of the lime. (See Refining.)

Bisulphite of lime.—The bleaching and cleansing action of sulphurous acid led to experiment upon its applicability to the defecation of cane-juice, and the first form in which it was employed was as a compound with lime, known as bisulphite of lime. About 1 per cent. or less of solution of bisulphite is added to the juice immediately it is extracted, or even while it is being extracted. Heat is then applied, and after the juice has been boiled and stirred for a few minutes, a mixture of cream of lime and clay-batter is added. The exact quantity of cream of lime is ascertained by test (p. 1886), sufficient only being used to produce neutrality. After boiling for 5–10 minutes, and beating down the scum, the contents of the clarifier are run into a subsider, and thence filtered out for concentration. The subsidence is not efficient without the addition of some weighting matter; but the syrup has a very fine colour, and gives a superior-looking muscovado sugar. An objection is the high price of the bisulphite.

Sulphurous acid.—Next came the separate introduction of the lime and the sulphurous acid into the juice. This system has grown into very wide use in the United States, W. Indies, and other places. There are two principal ways of carrying it into effect:—(1) By first passing sulphurous acid gas into the juice, and then adding lime: known as Col. Stewart's process, patented in Louisiana and the W. Indies, and recently adopted in Egypt and elsewhere; (2) by first adding the lime, and then passing the sulphurous acid gas: Beanes' system, chiefly employed in Cuba, but also in Java and Australia. The effect is probably identical in both cases. The first-described plan is far the most common.

At Aba-el-Wakf, the following plan has been introduced. As fast as the raw-juice tank is filled, its contents are raised to the clarifiers, steam at 60 lb. being turned on as soon as the bottoms are covered. When the juice begins to boil, it is stirred with a copper pipe, through whose lower perforated end, sulphurous acid gas is injected, and allowed to dissolve in the juice, till the colour of the latter becomes considerably lighter, and a decided separation of the flocculent matter takes place. The quantity of sulphurous acid to be added varies: approximately, 450 gal. would require the combustion of $\frac{1}{10}$–$\frac{1}{2}$ lb. of sulphur. The sulphurous acid is forced into the juice by an iron pump (with indiarubber flap-valves), whose speed can be adjusted to the quantity required. The gas is generated by the combustion of crude sulphur in a cast-iron D-shaped muffle, the necessary air being sucked through by the pump; as the combustion depends on the air-supply, and the latter on the speed of the pump, the whole apparatus is self-adjusting. Some 50–60 ft. of 3-in. cast-iron cooling-pipe, with numerous holes for removing "flowers" as formed, conduct the gas to the tanks.

As soon as the boiling juice is sufficiently "gased," milk of lime mixed with China-clay is added at the rate of $\frac{1}{2}$–3 gal. per 450 gal. of juice, till it is perfectly neutral; it is then let into subsiders to stand till the impurities have settled. The use of sulphurous acid necessitates the employment of about 4 per cent. additional lime. The combination of sulphurous acid and lime permits the production of a grey-white muscovado ("grocery") sugar.

Other Alkaline Earths.—It has been proposed to replace lime in defecation by other alkaline earths, such as barium and strontium. Their effect is more powerful than that of lime, but they have not come into general use on account of the prejudice regarding their poisonous qualities, and the risk of some being left suspended in the sugar. As regards barium, there is no proof of its deleterious qualities when present in such quantities as are found in sugar treated with it; but an expert can at once detect the use of any barium salt, by the modified form of the sugar-crystals, which modification shows that barium salts are still present, and hinders the sale of such products.

Lime sucrate.—This process is described under Refining.

Lead acetate.—Many years ago Dr. Scoffern employed the subacetate of lead ("sugar of lead") as a defecating agent, and many inventors have since improved on his method of manipulation. This carries down many of the impurities as a precipitate, leaving sugar in solution, and any possible excess of the lead salt is thrown down as insoluble sulphite by the injection of sulphurous acid. Sugar was prepared by this process, without any injury resulting, but an outcry against the poisonous nature of lead acetate, and the dread that some might be accidentally left in the sugar, caused the process to be officially condemned. Lead certainly was present in the sugar, but it is not known whether it was in a poisonous form or not.

Sulphur and Chlorine compounds.—One of the most recent innovations in defecating is the invention of Eastes, Lukin, and Boyd, of Brisbane, and known as "Eastes' process." The juice may be tempered and clarified either hot or cold, but the liquor must be heated to boiling-point to coagulate all the albumen. When the juice is in the clarifier, 4–8 oz. of chloride of sulphur are added to each 100 gal. of juice, according to the supposed quantity of albuminous matter present, the necessary quantity first being mixed thoroughly with a small quantity of the juice in a small vessel, and then gradually poured into the clarifier, whilst the liquor is agitated. In addition to the chloride of sulphur, in the case of juice containing free acid, sufficient lime must be used to neutralize it. Sulphide of lime and "chloralum" (chloride of aluminium) may replace the chloride of sulphur. After the application of the particular chemical selected, the liquor is brought to boiling-point, and allowed to rest for not less than 45 minutes, by which time the precipitate will subside, and a perfectly clear liquor remain. This is then run off to be evaporated.

Sulphur, Lime, and Charcoal.—John McGregor, of Tobago and Trinidad, has recently introduced a plan called the "arvation" process. It consists in burning sulphur, lime, and charcoal in a furnace, and conducting the fumes into the liquor; its advantages are nil.

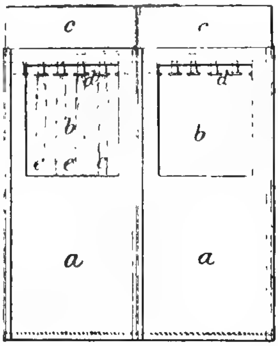
Yellow Crystals.—The beautiful Demerara "yellow crystals" owe much of their brilliant colour and transparency to delicacy of tempering. The temper used is lime-water rather than cream of lime, the density being only 10° instead of 17° B., and preference is given to rain over trench-water. The clarifier is filled with sulphured juice, tested repeatedly, while it is entering and while lime is being added, to ascertain the exact quantity of lime necessary: when it is known, the whole quantity is for the future introduced before the clarifier is one-quarter full.

The exact proportion of temper is decided (1) by the neutral reaction on test-paper, and (2) by the appearance of the limed and agitated juice when filled into a foot-glass placed in the light and allowed to subside for 5 minutes. The appearance wished for is brilliant transparency combined with a golden colour. The right quantity of lime is that which will give this result, though the liquor may be a trifle alkaline. With inferior juice, colour must be sacrificed for transparency, and lime added till transparency is attained, even though the colour be intensified to light-red. Too light a colour, which is sometimes compatible with good transparency in the case of superior juice, will result in a green-coloured sugar. Over-tempering causes the sugar to turn greyish-brown when cured. For the subsequent treatment of the liquor in the vacuum-pan, see pp. 1894–5.

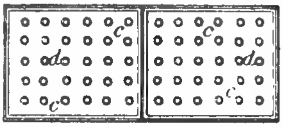
Filtration.—Filtration of the juice is a necessary adjunct to the defecation by heat and chemicals, its object being the removal of the matters rendered insoluble by these operations. The chief kinds used are bag-, charcoal-, and capillary filters.

Bag-filters.—The construction and arrangement of these are shown in Figs. 1358 and 1359. The filter consists of a wrought-iron case *a*, with openings at *b*, and an internal flange at top to carry a cast-iron box *c*, having holes in the bottom, for the reception of gun-metal bells *d*, to which are attached the cotton-twill filter-bags *e*. Fig. 1360 shows an enlarged section of the gun-metal bell *d*. The bags *e* fastened to these bells are 3–6 ft. circ. and 6–10 ft. long, woven without a seam. They are crumpled up inside "sheaths" of strong open webbing, about 18 in. circ., which restrict their expansion. They are arranged in series of 100 or more.

1358

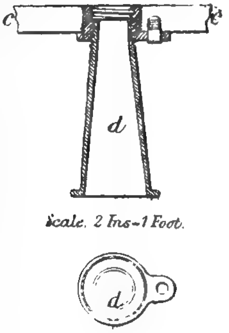


Scale ¼ Inch–1 Foot.



1359.

1360.



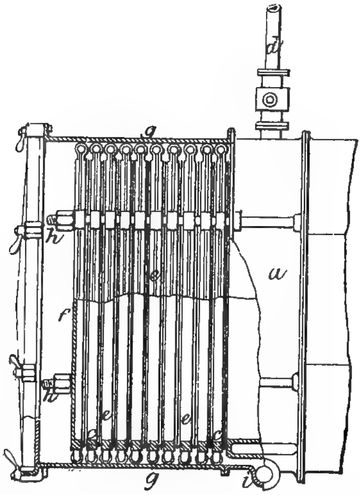
Scale. 2 Ins–1 Foot.

Charcoal-filters.—These are large, slightly tapering, cylindrical vessels, generally of wrought iron, with a perforated false bottom about 1½ in. from the bottom. A blanket covers this false bottom, to prevent the charcoal from being carried through with the liquor. Some charcoal, however, always accompanies the first liquor, which is caught in a separate receiver, to be filtered over again.. In filling these vessels, the first few inches of charcoal should be pressed compactly down, after which, it is packed lightly but evenly as near to the top as will leave a convenient space for the liquor. The object of these filters is to remove the vegetable colouring matter from the liquor, together with the fine suspended impurities that have escaped the bag-filters. Use is made of both animal charcoal (bone-black) and wood charcoal, but the former is in most general favour. (See also Beet-sugar, pp. 1851–4; Refining.)

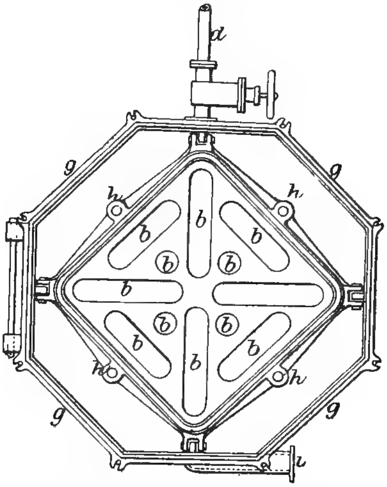
Capillary filters.—A representative filter of this class is that invented by F. A. Bonnefin, of Guadeloupe, and made by Corcoran & Witt, 30 Mark Lane, London. It is intended to be used in conjunction with his "continuous preparator" (see p. 1898), which effects the removal of the coarser impurities prior to the tempered juice entering the filter proper. This latter separates solid matters from liquid by capillary action taking place through fibres held between surfaces of a yielding material, and aided by pressure or suction. The bundles of fibres are usually, for convenience, woven into an exceedingly loose fabric, preferably of pure cotton. At one end, they are in contact with the mixture to be filtered; the capillary action of the fibres draws the clear liquid past the yielding surface, whilst the solid matters are left behind.

Figs. 1361–2 show an elevation partly in section, and a transverse section of one way of arranging the filter. The apparatus consists of a central chamber *a*, to which the material to be treated is supplied by a pipe *d*, pressure being obtained by a pump, or by allowing the material to descend from an elevated cistern. The two sides of the chamber *a* are slotted, as shown at *b*, to allow the free escape of the material on either side. The two faces of the chamber *a* are also grooved all round, and the grooves are filled with soft indiarubber *c*, so as to project above the face of the chamber *a*. Against the face, is placed the filtering fabric, of such a size as to overlap the indiarubber all around; holes are cut in it, corresponding to the slots *b*. Against the fabric, is placed a rectangular brass frame *e*, grooved and fitted with indiarubber in the same way as the faces of the chamber *a*. Another fabric is placed next, then another frame, and so on in succession. The alternating series of brass frames, filter-cloths, and indiarubber terminates in a cover-plate *f*.

1361.



1362.



The bolts *h*, fixed to the chamber *a*, hold the filter together. The outlet is at *i*. The material is admitted to the filter throughout its whole length by a gutter leading from the feed-pipe. Filtration takes place, not through the fabric, which is woven so loosely as to be transparent, but from its edges, the pure liquid traversing the fibres longitudinally till it escapes at the margin, while the solid matters are arrested, and range themselves concentrically upon the fabric around the indiarubber surface. A filter with plates 15 in. diam. and containing about 30 duplicate surfaces of fabric, will pass 120 gal. per hour. The dirty fabrics need only a few minutes' rinsing in hot water to cleanse them from the adherent solids, and are at once ready for re-use. The action of the filter is purely mechanical, and it is not capable of removing impurities in chemical combination or solution.

Galvanism.—W. Eathorne Gill, of London, proposes a system of defecating by galvanism in conjunction with chemical agents and filtration. Galvanic and chemical actions are set up by the use of zinc strainers and strips, coated with a composition whose base is clean grease, the other ingredients consisting of charcoal, metallic sulphides, silica, alumina, and any insoluble lime salt, reduced to powder, and intimately blended. A zinc strainer receives the juice, which escapes by the orifices into a surrounding separator, where the lighter impurities rise, while the heavier pass into a bed of clean sand. It is claimed that the combined effect of the composition and the galvanic action set up in the juice is complete defecation, and prevention of all fermentation. But the only efficient part seems to be the sand-filter, which has long been known and appreciated.

Concentration and Granulation.—The cane-juice, reduced to the condition of a clear solution of sugar (with some few salts as impurities) in water, has next to be deprived of so much of its water as will permit the sugar to assume a solid (usually crystalline) form. This operation, termed "concentration" and "granulation," has been described in principle on p. 1854. The inversion of sugar during concentration of cane-syrup is said to be prevented by the introduction of superphosphate of lime into the juice before boiling. There is no evidence as to the practical utility of this plan; but phosphoric acid appears rather to aid the crystallization of sugar (see p. 1850), and the process would therefore seem to be based on good ground. Both heat and cold have been applied to the concentration of cane-syrup, but chiefly the former.

Heat.—The means by which heat is applied to the evaporation of cane-juice may be described under five separate heads, according to their principles:—(*a*) Pans heated by fire, (*b*) pans heated by steam, (*c*) film evaporators, (*d*) vacuum-pans, (*e*) bath evaporators, (*f*) Fryer's concretor.

a. Pans heated by Fire.—The earliest and crudest system of evaporation was the "copper-wall," or "battery" of open pans called "teaches" (taches, tayches, &c.) The first two pans of the series are the clarifiers; thence the juice flows into the teaches, sheet-copper pans set in masonry on a descending plane. As the juice concentrates, each lower pan fills up with liquor from the one immediately above it, until the density of the liquor in the "striking-teach" permits granulation, when the mass is ladled into shallow wooden vessels, and conveyed away to be "cured." By the oldest method, the liquor was ladled throughout the series. More recently an improvement was introduced, consisting of a copper dipper, fitting inside the striking-teach, and having at the bottom a large valve, opening upwards and worked by a lever. The dipper is attached to a crane, which commands the striking-teach and the gutter leading to the coolers. This greatly economises time. The furnace for heating the series is set under the striking-teach; the heat passes by flues to the chimney or to the boiler-flue.

In working a battery, the difficulty is determining the exact moment when the boiling of the "sling" in the striking-teach must cease, i.e., when to make a "skip;" great skill and experience are required to suit each kind of juice. The main point is to bring about crystallization in the sling in as great mass as possible after it cools: if the sling be taken out too soon, there will be only a few large irregular crystals, and a quantity of sugar will be left in the molasses; if the sling be boiled too long, a sticky mass of tiny crystals and syrup will result, from which the molasses can only be drained off with great difficulty, and from which it is impossible to obtain clean, dry, and hard crystals. An experienced "wall-man" knows the approach of the striking-point; but a good test is the following:—Pour a spoonful of the boiling sling into a glass of clear water; if, after a minute's cooling, the sling can be formed into a ball which does not stick to the fingers, and slightly flattens itself on the bottom of the glass on being dropped in, the correct period has arrived for striking.

The continued use of the copper-wall is an illustration of the backwardness of the cane-sugar industry in many places. Its drawbacks are:—(1) Waste of fuel; (2) the amount of labour required and length of time occupied; (3) considerable waste of liquor in the sloppy manipulation; (4) the proportion of molasses produced is intensified by the churning-up of the liquor and consequent admixture of air, and by the irregular and uncontrollable action of the heat upon the surface of the metal with which the liquor is in contact. The temperature prevailing in the striking-teach is not less than 110°–113° (230°–235° F.) in any part, and much greater at the bottom of the mass. It is therefore not surprising that liquor showing 10 per cent. of inverted (uncrystallizable) sugar in the first pan, should have 22–23 per cent. by the time it is finished in the striking-teach.

b. Pans heated by Steam.—The simplest form of steam evaporating-pan consists of a rectangular wrought-iron tank, at the bottom of which is a series of copper steam-pipes, connected by gun-metal bands brazed to them, and carried on wrought-iron supports. The tank is fitted at the side with a steam-valve at one end of the steam-pipe range; at the other side, is a cast-iron box, fitted with a wrought-iron pipe, for the escape of the condense-water to a condense-box. This form of evaporator presents a large heating surface, with facility for cleaning. By passing the ends of the steam-pipe range through stuffing-boxes, the pipes can be turned up, and all parts of the interior of the tank be readily cleaned, a matter of great importance.

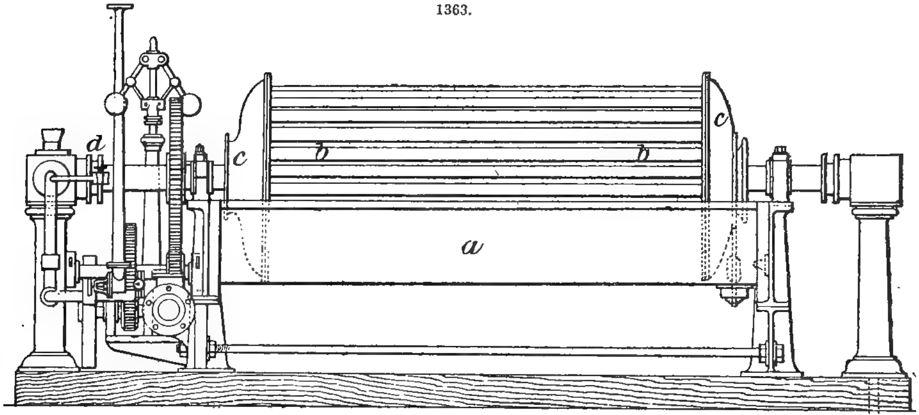
Under Pressure.—The 5 steam concentrating-pans erected at Aba-el-Wakf receive the juice when it has fallen to a temperature of about 71° (160° F.) Each consists of a copper tray, 23 ft. long and 6 ft. wide, heated by a steam-boiler beneath, and covered by a sheet-iron casing which confines the steam evolved from the juice. The steam-boilers work under 60 lb. pressure. The heating surface of each tray is increased by 495 vertical nozzles screwed into it; these are of brass, cast very thin, and slightly tapered. Their mean external diameter is 2⅛ in., and they project 4½ in. above the plate. If the juice is in good order, it makes very little foam; if not properly tempered, a thick froth soon forms, but appears to condense against the cover, and drop back into the boiling fluid. Each particle of juice takes about 18 minutes to pass through the tray, and though exposed to the temperature due to 3–4 lb. pressure of steam on its surface, the syrup gains hardly more colour than would be due to the increased density. The steam generated from the juice is collected into a wrought-iron main, and taken by one branch to the vacuum-pans, and by another to the vacuum-pumps and centrifugal-engines, which it actuates, supplying all the power necessary for boiling to grain, curing, and raising the water required throughout the mill. A great drawback to the use of steam from the juice is its low pressure (3–6 lb.).

The advisability of concentrating syrup under pressure in this manner has been the subject of much discussion. It is usually held that any temperature above 60° (140° F.) is prejudicial to sugar solutions, and that above 74°–77° (165°–170° F.) the proportion of sugar inverted to the uncrystallizable condition is very large. A perfectly white refined sugar exposed to a temperature of 107° (224° F.) for 3 hours becomes quite yellow. The normal boiling-point of syrup at 10° B. is about 101° (214° F.). In these pans, the extra pressure of 3–6 lb. of steam means an increase of 8°–16° F. in the temperature in order to arrive at the boiilng-point, which would seem to be highly injurious. Long exposure, however, is quite as mischievous as high temperature. It is easy to avoid one by incurring the other; the difficulty is to avoid both. Perhaps the chief harm of rapid concentration at a high temperature is the violent ebullition of the mass, whereby portions of heated surface are momentarily left dry. The Aba pans, working with a steam temperature of 143° (290° F.) on the under side, and the juice being at 105½° (222° F.), actually made less molasses (i. e. inverted and charred sugar) than some more generally-recognized plans. Still the system cannot be recommended for adoption where there is no necessity for using the water evaporated from the juice.

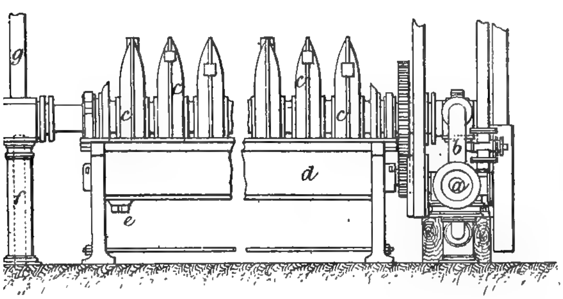
c. Film Evaporators.—Under this head are particularly included those evaporators which depend upon the principle of exposing thin films of liquid to the action of a heated surface in the open air. They are generically known as "wetzels" among planters, and comprise the "pans" bearing the names of Gadsden, Wetzel, Schroeder, and Bour, and many modifications, some of which, such as Murdock's, have steam-heated coils. The original form was Aitchison's simple cylinder revolving with partial immersion in the liquid, and heated internally by steam. In its revolution, the cylinder carries on its surface a film of liquor, whose water is soon evaporated. In the Gadsden pan, the cylinder is replaced by a skeleton cylinder, consisting of two metallic discs connected by a series of metallic rods fixed at short intervals around the periphery of each disc. Here the drawbacks are the churning of the liquor (except at very low speeds), and the insufficiency of the heat derived from the steam-jacket of the pan.

Wetzel's improvement upon this is the substitution of steam-pipes for the solid rods. This overcomes the deficiency of heat, and has been very generally adopted, though the churning is not reduced. Fig. 1363 shows the Wetzel pan and its special engine, as made by Fawcett, Preston, & Co., Liverpool. The pan *a* contains the liquor; the pipes *b* are heated by steam passing through them; and the whole cylinder *c* is caused to revolve by the engine *d*. The large heating surface enables steam at very low pressure to be used, exhaust-steam from the cane-mill engine being sometimes utilized for the purpose. By fitting the pipes diagonally (instead of horizontally) between the discs, the churning is modified, but not altogether prevented. The greater exposure to the air also causes increased oxidation of the juice and inversion of the sugar.

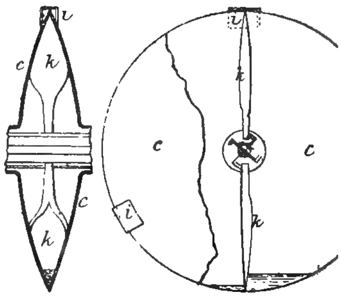
1363.



1364,



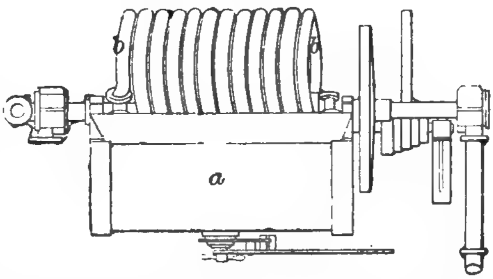
1365.



Schroeder overcomes the churning by having a jacketed pan fitted with a set of revolving solid metallic discs strung upon a square shaft, and fixed about 6 in. apart. The apparatus has the additional advantage of cheapness, but the heat derived from the steam-jacket requires to be supplemented by a coil of steam-pipe winding between the discs, which constitutes an evil.

Bour, observing that larger grains of sugar are produced on the discs in Wetzel's pan than on the pipes, concluded that hollow steam-heated discs would increase the evaporating surface, and produce better grain. A front elevation of his pan is shown in Fig. 1364; and vertical and transverse sections of the disc on an enlarged scale in Fig. 1365. *a*, is the steam-engine; *b*, exhaust-pipe to heat the revolver; *c*, revolver consisting of 10 copper discs; *d*, copper pan for holding the liquor under treatment, and discharged by the valve *e* at bottom; *f*, pipe for carrying off the condensed water from pan; *g*, pipe for carrying off air and uncondensed steam; *h*, safety-valve. The discs are mounted on an axis which allows the steam to communicate freely with them, at the same time collecting the condense-water and carrying it off at one end. Inside each disc are 2 spoons *k*, running from the extreme diameter and terminating in the axis, into which the water is delivered. Outside the discs *c*, are small buckets *i*, which lift the liquor as the discs move round, and spread it as a thin film over the surface which is not immersed. The speed of the revolver is 10–20 rev. per minute. Where steam is plentiful, equally good sugar is produced by the quicker speed, and nearly double the work is performed in the same time. One pan cooks 12 cwt. of sugar per hour, from 20° B., as taken from the battery, the temperature never exceeding 77° (170° F.). The distributing-cups churn the liquor excessively.

1366.



One of the most recent modifications is Pontifex's, shown in Fig. 1366. The pan *a* contains the liquor to be evaporated, within which revolves a coil of steam-pipe *b*. Thus a large heating-surface is obtained, without the drawback of churning up the liquor.

It is to be observed that all these forms of film evaporator are destined only to finish the concentration begun in the battery. The liquor is brought to them at a density of 26°–27° B.

d. Vacuum-pans.—The principles controlling the boiling of juices *in vacuo*, and the details of the construction of vacuum-pans and their accessories, have been already given under Beet-sugar (see pp. 1856–7).

Figs. 1367–1370 show vacuum-pans as used on nearly all large sugar plantations. The grain formed from syrups boiled *in vacuo* is larger and more solid than that from syrups simply concentrated to crystallizing-point in open batteries. A Cuban hogshead will contain only 1600 lb. of sugar made in a copper-wall, but 1800 lb. of vacuum-pan sugar. By the use of the vacuum-pan also, the planter is enabled to boil his molasses, and to extract from 1 gal. some 4–5 lb. of sugar, still having a second molasses for the distillery.

Working the Vacuum-pan.—The air-pump is started, and so soon as the vacuum reaches 26–27 in., the feed-cock on the side of the pan is opened, and sufficient liquor is drawn in to completely cover the first coil; steam is next turned in, and the liquor rapidly concentrates; fresh supplies are admitted at short intervals, the feed-cock being opened say for 15 seconds at a time, until the mass commences to show "grain." The grain is fed carefully, the cock being opened frequently, and each time the quantity admitted is increased. As the amount of sugar in the pan continues to augment, steam is turned into the 2nd and 3rd coils, until, at the completion of the charge, the pan is nearly full, or just below the sight-glass. In this way, the grain "grows" in size. On the conclusion of the boiling, the vacuum is destroyed, and the charge is run out into a tank, and allowed to stand for an hour or two, when a further crystallization takes place.

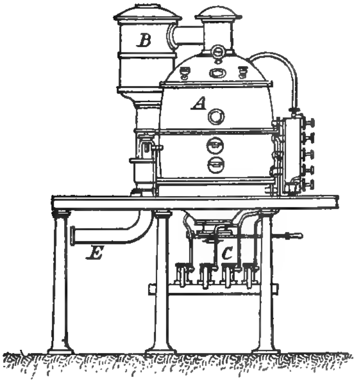
It is customary to draw in as much syrup as will cover the bottom coil (when reduced by concentration), called "graining low-down." Some prefer to grain higher; some when the pan is half-full. An objection to graining high is that the grain has not so much time to grow, but it does not always hold good. A pan taking 7 hours to boil a strike of 8 tons of *masse-cuite* (concentrated juice) grained low, will only take 6 hours if grained higher. The crystals in the second case will not be so large, but, in an 8-ton pan, they will be of fair size, even by the quicker method. The drawing-in is conducted thus:—The charging-cock is opened, and shut off again as soon as the liquid boils up to the "bull's-eye" on the opposite side. The contents quickly boil down; the cock is opened again, and shut off as before when the liquor boils to the same height. This is kept on until the syrup intended to form grain has been taken in: roughly speaking, 2000 gal. of good 18°–20° B. syrup to a 5-ton pan is about the correct amount.

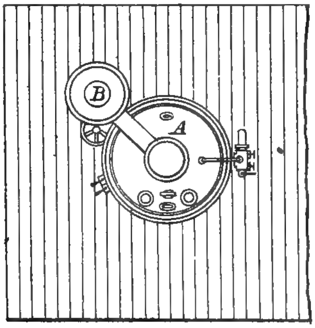
The granulating-point is easily recognised by a practical pan-boiler: a "proof" of the syrup, taken between the thumb and finger, should draw to a thread $\frac{3}{4}$-in. long; but this test is of no value if the syrup is sticky, resulting from under-tempering or sour canes.

In boiling for large grain, it is essential to grain low. The grain commences to form in minute specks; these rapidly increase in number and size, until the whole mass of liquor is filled with them. As each lot of syrup is admitted, it deposits on the grains already formed, causing these to grow larger. During granulation, the temperature should never be more than 71°–78° (160°–172° F.), though raised later on to harden the crystals; but this must not be done too soon after graining, or the crystals will melt.

Rules for graining syrup in the vacuum-pan are:—The thinner the syrup admitted, the bigger will the crystals be; for large-grain sugar, few and heavy charges must be admitted, so as to give the grain time to grow; the larger the crystals are required, the more quietly and slowly must the boiling be carried on; to make regular grain, granulation is brought about very slowly, and on no account must the grain be forced by boiling very high before the first charge.

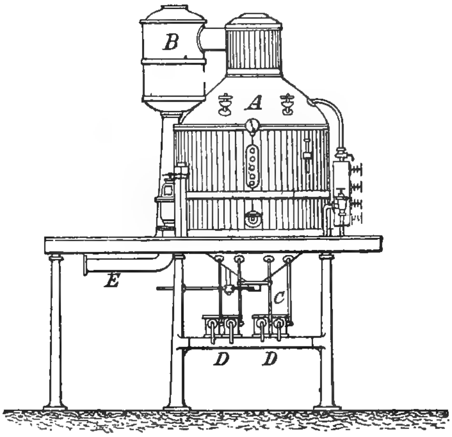
1367.

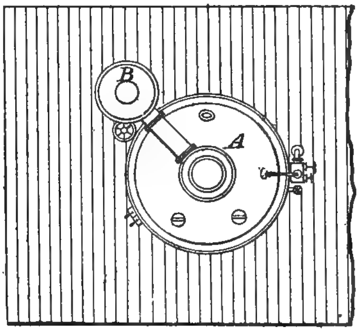




1368.

1369.





1370.

It is important in pan boiling to avoid forming "false grain." The two stages when the danger of it is greatest are:—(1) The time when the sulphuric acid (for producing "yellow crystals") is admitted into the pan; (2) the "opening" of the sugar when re-starting the pan to "double," i. e. when, having struck out half the contents of the pan, fresh portions of syrup are admitted on to the *masse-cuite* left in the pan. If the contents are not sufficiently high when sulphuric acid is admitted, false grain forms whilst working up for striking. Unless the *masse-cuite* be "opened" very slowly, the new lot of syrup, instead of depositing on the already-formed crystals and increasing their size, will form an independent grain, called "false grain," which not only spoils the sugar, but prevents the molasses leaving it in the centrifugals.

When false grain is very bad, the best course is to strike it out immediately, and spin it in the centrifugals, mixing it with warm water if absolutely necessary. When not very bad, and the pan is little more than half-full, the heat and washing of a few heavy charges of new syrup will remove it.

Demerara "yellow crystals."—Sulphuric acid imparts to the sugar the delicate yellow bloom so much admired in "Demerara crystals," instead of the ordinary green-grey colour. If too little is mixed with the *masse-cuite* in the pan, the colour is scarcely improved; if too much, the sugar turns quite red a day or two after curing. It is admitted last of all; pan-boilers should not be allowed to make a charge of syrup on to it immediately previous to striking. The quantity of acid to be used depends on the colour of the *masse-cuite*; as a rule, 3 gal. of acid diluted with 1¼ gal. of cold condensed water to 5 tons of sugar is about right. In all cases, the least possible quantity should be used compatible with securing the desired result.

The proper striking-point is of great importance, and arrives when the proof will scarcely run out of the socket of the proof-stick. *Masse-cuite* on leaving the pan should have a light-red colour tinged with gold, and a temperature of 66° (150° F.)—never higher. The objects of doubling are to increase the size of the grain, so that the market value of the sugar may be enhanced, and to save time. Some syrup makes sugar that will bear doubling 2–5 times; while some gets sticky after the 1st cut of the pan. Great care must be taken while opening the *masse-cuite* left in the pans; for the 3rd or 4th cuts, a temperature of 74° (165° F.) may be maintained while opening slowly and carefully, the operation requiring 15–25 minutes. The drawing-in of syrup demands more care in subsequent cuts than in the first.

Great loss of sugar is caused by doubling, depending on the amount of acid used, and on the quality of the syrup; it is estimated to amount to 20–25 per cent. of the sugar, and some hold that a better return is obtained from the larger quantity of dark sugar at a lower price; but on the other hand the "loss" means sugar converted into a high class "golden syrup," and the extra market value of the yellow crystals is affirmed by some of the best authorities to more than atone for the extra cost and increased inversion of crystallizable sugar.

When sour canes are sent to the buildings, the sugar is apt to get sticky in the pan, and occasionally to such a degree as to interfere with the formation of grain, and endanger the whole strike of sugar. If the stickiness is not very bad, 2–3 buckets of strong lime-water, taken into the pan through the acid-cock, will put things straight. Besides this, the excess of acidity should be neutralized by lime-water, leaving the syrup only slightly acid before drawing into the pan.

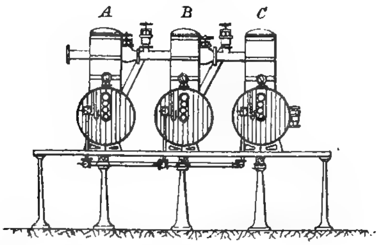
Molasses.—"First molasses" runs from *masse-cuite* which has had no molasses boiled into it; "2nd molasses" drains from *masse-cuite* boiled with molasses in it; "3rd molasses" drains from vacuum-pan molasses-sugar (not muscovado sugar). These are kept distinct. Third molasses is so sticky and impure that it is sent to the rum distillery (see Alcoholic Liquors—Rum, p. 228), as is also sometimes the case with 2nd molasses, when low quotations do not pay to convert it into sugar. Only 1st molasses should be used for mixing with syrup-sugar in the pan, and 2nd molasses for boiling molasses-sugar ("3rd sugar"); 2nd molasses should never be used for boiling with pure syrup-sugar in lieu of 1st molasses. There is a great difference of opinion about the boiling of molasses; but the plan now to be described is the best, provided arrangements permit the molasses to be boiled within 1–2 hours of separation in the centrifugals.

Supposing that the pan has struck out 3 tons, been refilled and cut a second time, leaving it still half-full, for a third time fresh molasses tempered with lime-water, and reduced with water to 30° B., is drawn in. The contents, struck out and "spun" in the centrifugal, should yield 2½–3 tons of 2nd sugar, i. e. syrup-sugar with which molasses has been boiled, giving about 1·2 tons of sugar from molasses, much improved in colour, in addition to the 2 tons obtained from the syrup, and upon which the molasses was admitted. To make a very pale sugar, this process will not answer, and the molasses must be made into fine quality 3rd sugar, or into rum.

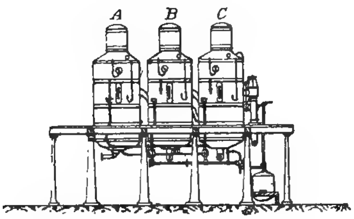
For tempering molasses, lime-water should be stirred in until most of the acidity is destroyed, and only a faintly acid reaction is shown on litmus-paper. For 2nd and 3rd syrups, or molasses which is to be boiled for grain, the density must be reduced to 30° B., either by blowing in live steam, or, if this be inadmissible, by the addition of condensed water. The boiling is performed in an exactly similar way to 1st syrup, except that it is useless to try for large grain, as the impurities effectually prevent the grain from increasing beyond a certain size. It is not an unusual custom to considerably raise the temperature before striking, by dropping the vacuum 2–3 in.; this is readily done by checking the supply of water to the condenser, and keeping the steam full on the coils and jacket. The temperature of the *masse-cuite* is then about 77° (170° F.), whereas it has previously been about 68°–74° (155°–165° F.). The object of this is to harden the grain, in order that it may be washed in the centrifugal. The *masse-cuites* from 2nd and 3rd syrups should always be allowed to stand 2–3 days in coolers, to "grow" the crystals before centrifugaling. Molasses from 3rd sugar of about 34°–36° B., are always "jellied" or "boiled smooth," and it is not then necessary to reduce the density. If very acid, they should be nearly neutralized, and boiled until a proof will draw out in a thread 1–1½ in. long between the finger and thumb. At this stage, and before any sign of granulation has commenced, the contents of the pan are discharged into a cooler, and allowed to stand for 1–2 weeks, until the sugar has properly granulated, before centrifugaling.

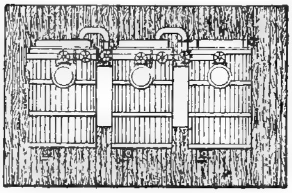
Multiple-effects.—Figs. 1371, 1372 show an elevation and plan of a set of horizontal triple-effect apparatus by Fawcett, Preston, & Co.; and Figs. 1373, 1374, an elevation and plan of a set of vertical triple-effect apparatus by the same firm. This apparatus enables the planter to make use of all the exhaust-steam that can be collected in the sugar-house, gives a syrup in good crystallizable condition, and saves labour. It also permits the use of a vacuum-pan in many places, where with a double-effect or a simple evaporating-pan it would be impossible, on account of scarcity of water. The exhaust-steam enters the heating-space of the pan C, and is condensed by the juice contained in the tubes. The first pan C is therefore a surface-condenser, and requires no injection-water; and the condensed water runs away to a receptacle, to be used again in the boilers. The vapour from the juice in C passes into the interior of B, producing a second ebullition, and is condensed here again by surface-condensation. The condensed water from this pan is water of vegetation, as it comes from the cane-juice; it is taken for washing the animal black. Finally, the vapour from B enters A, and the vapour formed in A is condensed by direct injection. As, therefore, injection-water is only used for condensing the vapour formed in the pan A, great economy is obtained. Triple-effects can be constructed either of vertical or of horizontal vacuum-pans. Each system has its advantages, but when equally well constructed and worked there is little or no difference in their results. On the whole, it may be said that the horizontal system does not require such expensive machinery and such good execution as the vertical.

1371.

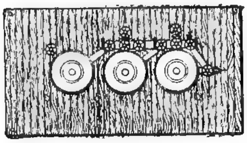


1373.





1372.



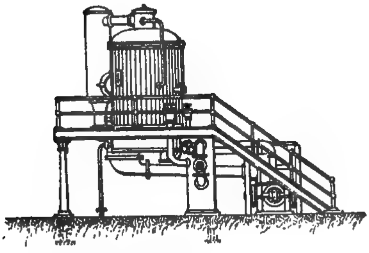
1374.

The saving in labour secured by the employment of triple-effect apparatus may be conveniently illustrated by some actual figures obtained on two similar estates, with syrup and sugar of identical quality and value, and under equally able management. On the estate using open batteries and a single vacuum-pan, the labour (negro) was as follows:—17 hands at centrifugals, 25 at batteries, 4 at vacuum-pan and engine, 8 collecting fuel, 4 at steam-boiler: total, 58, working 18 hours a day = 1044 hours of labour. The second used a juice-heater, defecating- and subsiding-tanks, a triple-effect, and a vacuum-pan, and employed the following labour:—12 hands at centrifugals, 3 at triple-effect, 2 at vacuum-pan, 4 collecting fuel, 6 at steam-boiler, 3 engineers, 4 at defecators, 2 at scum-tanks, 2 at syrup-tanks, 2 at molasses-tanks; total, 40, working 13 hours a day = 520 hours of labour. Each factory turned out 13 tons of 1st and 2nd sugars per diem.

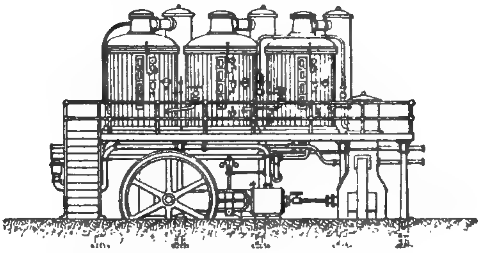
Figs. 1375–1378 show an arrangement by Manlove, Alliott, Fryer, & Co. In each pan, is a vacuum above the boiling liquor—slight in the 1st, better in the 2nd, and very complete in the 3rd. This is attained by a vacuum-pump, driven direct by a steam-engine, and similar to the vacuum-pump of an ordinary vacuum-pan. The flow of the liquor through the three pans is continuous, no stop requiring to be made for the discharge. The vapour rising from the boiling liquor in the 1st passes through a "save-all" (which catches any priming juice) into the steam-drum of the 2nd, whence it is removed as condense-water after giving up its latent heat to boil the liquor around it. Similarly, the vapour from the liquor thus set boiling in the 2nd passes through a save-all into the steam-drum of the 3rd, where in turn it condenses itself, parting with its latent heat to the liquor now in the 3rd stage of concentration. The vapour rising in the 3rd pan, being at so slight a tension as to part with its latent heat only at a temperature too low for it to be further utilized, passes through a save-all to a condenser, whence it rushes as condense-water into the pump. Thus almost all the heat supplied to boil the liquor and evaporate its water is used again to repeat the operations to a further extent in the 2nd and 3rd pans. Hence the economy of fuel, as compared with ordinary steam evaporating-pans. The temperature of the liquor in the 1st pan is below that of the same liquor boiling in the open air; it is reduced for the denser liquor in the 2nd pan, and still further for the most concentrated liquor in the 3rd pan, in consequence of the progressive completeness of the vacuum.

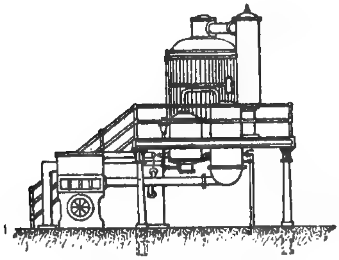
Rillieux's Triple Apparatus.—Norbert Rillieux's improvements in triple-action apparatus, with the object of attaining a maximum useful effect, are as follows:—The recipient for discharge-steam

1375.

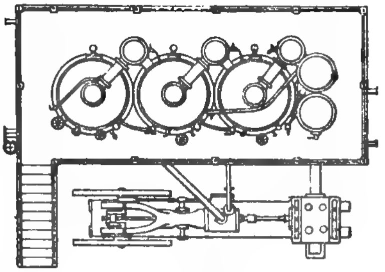


1376.





1377.



1378.

(A, Fig. 1379) is provided with an equilibrium-valve C, which regulates the maximum quantity of steam that can be used. The first recipient being the steam-generator of the entire apparatus, and heated by the discharge-steam of all the engines, is also connected with the discharge-water from the coils of the boiling-pan D through the check-valve *a* and pipes *b*. By this means, the small excess of steam that escapes with the water, assists in heating the first pan, while the combined condense-water from the coils and pan passes off through another pipe *d e* into a reservoir *g* for the feed-pump to the generators.

To effect boiling with double action, considerable pressure is required in the first pan,—½–⅔ atmos., and even more, according to the size of the coils. The vacuum is very small in the second pan. The pressure is regulated by introducing into the feed-vessel for the triple-action a sufficient quantity of direct steam, so that it does not interfere with the action of the apparatus. To maintain normal pressure in the first pan, special apparatus is provided. If the boiling-pan is heated by direct steam at high pressure, the discharge is conveyed to the 1st evaporating-pan; if steam from the expansion-chamber is used, or escape-steam from the engines, the discharge from the boiling-pan is conveyed to the 2nd evaporating-pan; if steam from the 1st evaporating-pan is used for boiling, the discharge passes to the 3rd evaporating-pan, and thence to the condenser. In triple-action apparatus, the 1st evaporating-pan is provided with two small auxiliary pans, one to evaporate the syrups that have been subjected to osmosis, the other for evaporating the saline liquors, both being connected to the same condensing-column. Improvements are also made in the pumps for drawing off the condense-water from the 2nd and 3rd evaporating-pans. To obtain maximum effect from the apparatus, it is necessary to maintain a considerable vacuum in the last pan. The condensation is effected by bringing the steam into contact with very extended surfaces, over which water flows in thin films, thus obtaining a very complete contact of the steam with the water. The steam from the safety-chamber is, as usual, subjected to a water-jet.

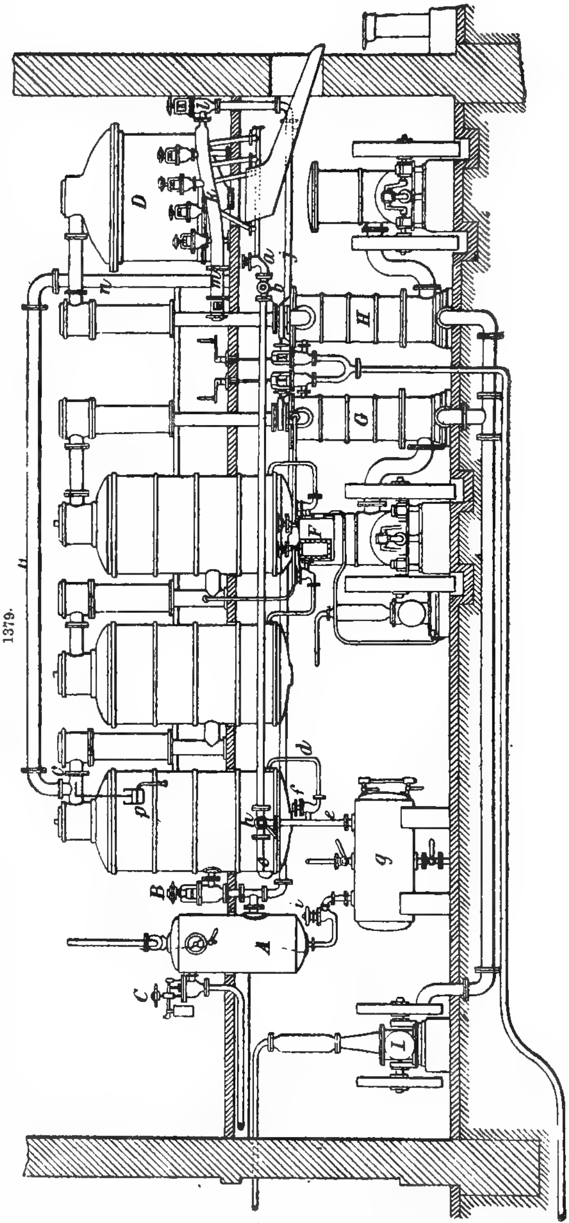
The system is receiving considerable attention from beet-sugar makers in France, though devised more especially for cane-sugar. One manufacturer, whose diffusion process gives a very low juice (sometimes only 2½° B., and generally not more than 3½° B.), states that with the ordinary arrangement of the triple-effect he evaporated 1800 *hectol.* (of 22 gal.) of juice at 3·2° B., with 150 *hectol.* of milk of lime, making a total of 1950 *hectol.* to 18° B. per 24 hours; with Rillieux's modification, he evaporated to 25° B., which, with the increased quantity worked off, is equal to a total evaporation of 5158 *hectol.* per 24 hours, or a gain of 3208 *hectol.* This gain is said to be effected at the cost of only a little (quantity not stated) additional steam. The Rillieux apparatus is now rarely used in Louisiana, being considered too complicated for plantation purposes; the tendency there is towards very large single vacuum-pans.

e. Bath-evaporators.—This system may be illustrated by the plan adopted by F. A. Bonnefin, of Guadeloupe, whose capillary filter has already (p. 1889) been described. The apparatus is intended for use with the filter, and is made by the same firm.

The tempered juice, prior to evaporation, passes through a "continuous preparator," a metallic vessel 32 ft. long and 18 ft. broad, divided by partitions into 4 chambers of 2 ft. in width; each chamber has a central partition not quite extending to one end, with holes for the inlet and outlet of a heating liquid, which therefore travels 36 ft. in the chamber, on leaving which it is reheated. On the partitions, is a copper pan divided so as to form a continuous zigzag channel, about 1100–1700 ft. long, the bottom being immersed in the heating liquid circulating in the chambers below. The juice is admitted at one end, and issues at the other. Along one side of the pan, are hollows to collect the heavy bodies deposited during the flow of the liquid.

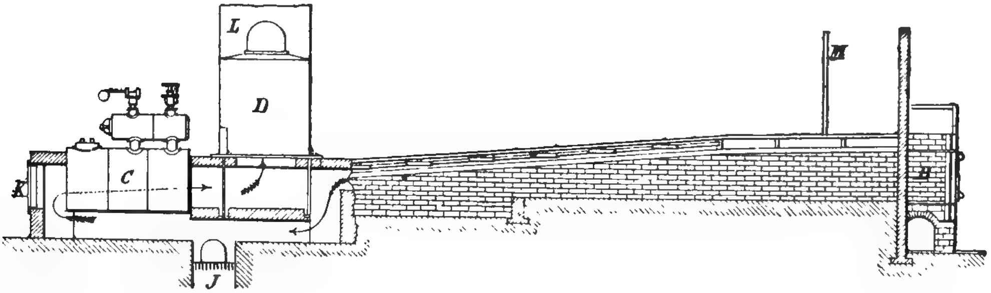
The juice, introduced at 15° (59° F.), being in contact during a travel of 1100 ft. or more with a liquid at about 99° (210° F.), leaves the further end of the pan at 80°–90° (176°–194° F.), deprived of heavy organic or inorganic matters in suspension, and of light matters which become separated and rise to the surface. It successively fills capillary filters (p. 1889), and is delivered in a pure state to be concentrated.

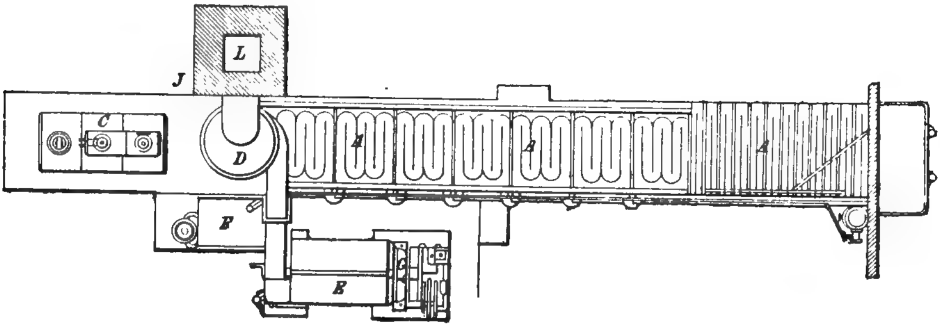
The vacuum-pan is constructed like the preceding, with modifications to maintain the heat in the coils at about 99° (210° F.), the heat being regulated in proportion to the juice being more and more concentrated, and always below 100° (212° F.) For generating heat, Bonnefin employs a small furnace for heating oil to 250°–280° (482°–536° F.). This hot oil is conveyed through a coil of pipes in a vessel containing water, and connected with the vessel which receives all the condense-water of the factory. After the oil has done duty in the evaporating apparatus, it is returned to be reheated by the furnace.


1379.

f. Fryer's Concretor.—In Fryer's concretor, no attempt is made to produce a crystalline article, but only to evaporate the liquor to such a point that when cold it will assume a solid (concrete) state. The mass is removed as fast as formed, and being plastic while warm, it can be cast into blocks of any convenient shape and size, hardening as it cools. In this state, it can be shipped in bags or matting, suffering neither deliquescence nor drainage. The cost of an apparatus capable of making 10 cwt. per hour is about 1000*l.* It is the invention of Alfred Fryer, of Manchester and Antigua, and is made by Manlove, Alliott, Fryer, & Co., Nottingham and Rouen. It is shown in side elevation and plan in Figs. 1380, 1381. It consists of a series of shallow trays A, placed end to end, and divided transversely by ribs running almost from side to side. At one end of these trays is a furnace B, the flue of which runs beneath them; and at the other end, are a boiler C and an air-heater D, which utilize the waste heat from the flue, employing it both to generate steam and to heat air for the revolving cylinder.

1380.





1381.

The whole series of trays A is placed on a slight incline, the upper end being next the furnace. The topmost 3 trays are made of wrought iron, since the intense heat here would render cast-iron liable to fracture. The clarified juice from the pipe M flows first upon the tray nearest the furnace; it runs down the incline towards the air-heater D, meandering from side to side in a shallow stream. Thus it has to traverse a channel 400 ft. long, before it can leave the trays at the end adjacent to the air-heater, although the distance between the furnace and the air-heater in a direct line is not quite 50 ft. While flowing over these trays, the juice is kept rapidly boiling by means of the heat from the furnace; and although it only takes 8–10 minutes to traverse, its density is raised from about 10° B. to about 30° B.

From the trays, the thickened syrup flows into the tank F, and thence passes out into the revolving cylinder E. The cylinder is full of scroll-shaped iron plates, over both sides of which the thickened syrup flows as the cylinder revolves, and thus exposes a very large surface to the action of hot air, which is drawn through it by means of a fan G. Motion is given to the whole apparatus by means of a small engine. In this cylinder, the syrup remains for about 20 minutes, and at the end of that time, flows from it at a temperature of about 91°–94° (195°–200° F.), and of such a consistency that it sets quite hard on cooling. By the use of dampers, the hot gases from the flue may be directed either under the boiler, returning through it to the heater, or direct to the heater. At J, is an auxiliary furnace for raising steam, when the heat from the concretor flue is insufficient or not forthcoming,—as, for instance, when beginning to crush canes, and before the juice has covered the trays. K is a smoke-door for cleaning out the boiler-tubes. L is a chimney, either of brick or iron, for the last escape of the gases.

F. J. G. Minchin, of the Aska Sugar Works, Ganjam, Madras, gives the following result of using

Fryer's concretor with diffusion-juice. It was in work 2 months, during which period there ran over it 1,030,680 gal. juice, and were delivered from it 500,225 gal., hence it evaporated 530,455 gal. This gives a daily evaporation of 9557 gal. For this, wood fuel was used at the rate of about 15 tons per diem. The juice ran on at 6°–6½° B. cold, and ran off at 11°–12° B. cold. The concretor was used as an auxiliary to double-effect.

W. F. Ashby has published some statistics of the use of the concretor by the Umhloti Sugar Co., Natal, from which it appears that with the 1876–7 crop, 610,900 gal. of juice gave 507 tons 6 cwt. 3 qrs. 7 lb. of sugar, or 1·86 lb. per gal. of juice; the 1877–8 crop gave, from 586,300 gal. of juice, 450 tons 15 cwt. 1 qr. 14 lb., or 1·72 lb. per gal. of juice.

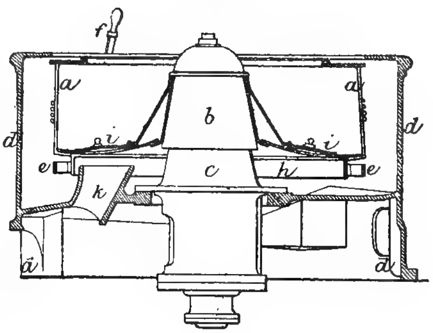
B. By Cold.—More than 30 years ago, Kneller proposed to concentrate syrups by forcing cold air through them, and his plan was much improved by Chevallier. Sugar made in Chevallier's apparatus rivalled that of the vacuum-pan in every respect. A vessel holding 200 gal. of syrup (comprised of 3 parts of sugar to 1 of water) is estimated by Wray to turn out 12 tons of sugar daily. The cost of the apparatus is small; the power required is trifling; the ordinary air of the estate could be used at once in dry weather, and would entail an insignificant expense for drying in damp weather; and the quality of the sugar is unsurpassed. In 1865, Alvaro Reynoso proposed to rapidly cool the syrup in suitable machines, and thus form a confused mass of particles of frozen water (ice) and dense syrup. The mixture is afterwards separated in centrifugals, and the syrup deprived of ice is evaporated *in vacuo* ready for crystallization. It seems most singular that, in the face of the many drawbacks and great cost incurred by concentration by heat, and in presence of the many improvements introduced of late years into refrigerating and cold-producing apparatus (see pp. 1017–20, 1134–42), so little effort is made by sugar-growers to adapt the latter system to their needs. A similar crystalline product, namely common salt (see p. 1718), is obtained by hundreds of tons from sea-water by the effect of natural cold, in favourable localities; and there would appear to be no valid reason why a modification of the plan should not succeed on an extensive scale with sugar solutions.

CURING.—"Curing" embraces the drying and whitening or bleaching of the sugar. The several plans will be discussed in succession.

Simple Drainage.—This is the oldest and crudest method. To remove a certain amount of the molasses and other impurities, the semi-liquid mass, dug out of the coolers as soon as sufficiently cold, is placed in casks with perforated bottoms; the holes in the casks are loosely filled with canes, twisted leaves, or rushes (the latter long enough to reach above the contents of the casks), in such a manner as to form a rough strainer. The casks stand meantime on rafters over an immense tank. Here the draining process slowly and imperfectly goes on, a portion of the molasses escaping into the tank below, but much still remaining in the mass of sugar, imprisoned between the minute crystals. Even after months of standing, the separation of the molasses is so incomplete that very great leakage and waste continue while the sugar is on its way to European markets. Sugar cured in this way is termed "muscovado," and is the most impure form of "raw" ("grocery," "moist," or "brown") sugar. It is nearly obsolete in the English and French colonies, and its manufacture is decreasing rapidly in Louisiana.

Claying.—The first improvement introduced is based upon the fact that the impurities of muscovado sugar are much more soluble in water than the sugar itself: thus washing with water effects considerable purification. The earliest manner of carrying this out was by placing the sugar in inverted cones with a minute aperture in the apex, stopped up during the filling and for about 12 hours afterwards; upon the mass of sugar in the cone, was placed a batter of clay and water (hence the term "claying"), the object being to ensure a very gradual percolation of the water through the mass. This water carries with it the uncrystallizable sugar and colouring matters imbedded between the crystals. The resulting sugar is much lighter-coloured than muscovado, but the grain is very soft, and the operation is most wasteful. In Bengal, a wet rag is sometimes substituted for the clay batter. The process continues but little in vogue.

1382.

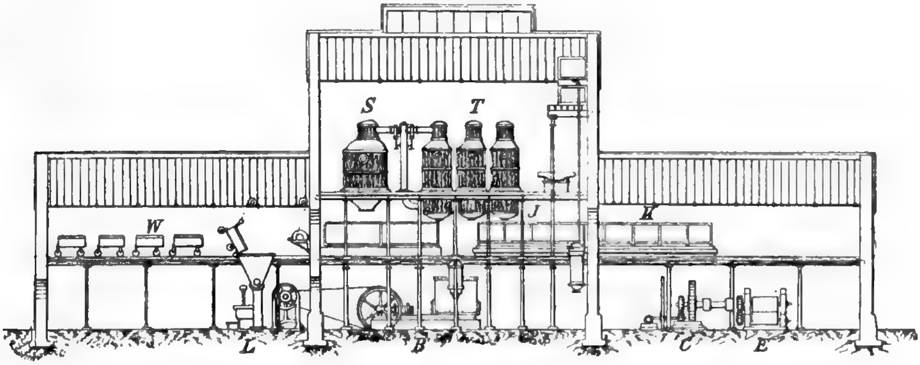


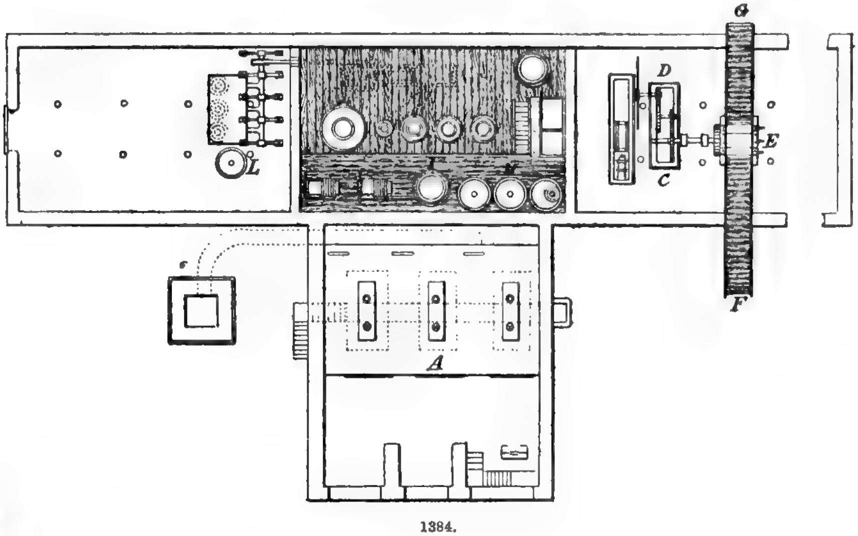
Spirit-washing.—The very slight solubility of sugar in alcohol, coupled with the ready solubility in that medium of many of its impurities, suggested the practice called "spirit-washing." This consists in substituting cold alcohol or alcohol and water for simple water. The results are not perfect, however, and the costliness of the method soon caused its abandonment in this connection.

Vacuum-chest.—The vacuum-chest consists of an iron box with a tray of wire-gauze above, and connected with air-pump suction below. The sugar is spread on the tray, and the downward suction produced by working the air-pump creates a tendency in the fluid portion of the mass to separate itself. Effectual separation, however, can only be attained when the grain or crystal of the sugar dealt with is large, hard, and well formed; with small or soft grain, the process is utterly inapplicable. This fault has restricted its use.

Centrifugals.—The preceding modes have been generally superseded by centrifugal machines or hydro-extractors. There are many varieties, but all consist essentially of a cylindrical basket revolving on a vertical shaft, its sides being of wire-gauze or perforated metal, for holding the sugar. The basket is surrounded by a casing at a distance of about 4 in., the annular space thus left being for the reception of the molasses, which is expelled by centrifugal force through the sides of the basket when the latter revolves at high speed. A spout conducts the molasses to a receiver. An example of a simple centrifugal is shown in Fig. 1382; more complicated forms are used in refineries (see Refining). The machine comprises a revolving basket *a*, carried by a cast-iron dome *b* upon a central shaft, arranged with driving-pulley, footstep, and neck-bearing, on the central bracket *c*, the whole being supported by the outer cast-iron casing *d*, which collects the liquid thrown off from the material in the basket, and conveys it away through a discharge-pipe. The brake *e*, for stopping the motion of the basket, is applied by the lever-handle *f* acting upon the angle-iron ring *h* riveted to the cylinder bottom. The sugar is discharged through two copper doors *i* covering openings in the cylinder bottom, and passes down the shoot *k* cast in the outer casing, into a receptacle below. The treatment of the molasses separated from the sugar has been already described (see p. 1895).

1383.





1384.

Complete Factory.—Figs. 1383, 1384 represent a modern sugar-house of economical and convenient design. The cane-mill and engine for driving it, with its cane-carrier and begass-carrier G F, are shown on the right. The steam-boilers are in the house A. The defecators are shown at H, and the clarifier at I. After the juice is defecated, it passes through the triple-effect T, where it becomes syrup, and is clarified in I, whence it goes as required to the vacuum-pan S, where it is concentrated and becomes *masse-cuite*, of larger or smaller grain as desired. From S, it falls into waggons W, and from these waggons it is discharged into the mixer of the centrifugals at L. These centrifugals are driven by the engine B, which works the vacuum-pump for the triple-effect and vacuum-pan. The sugar is finally packed in the area P, and delivered at the door on the extreme left of the house.

Maple-sugar.—The rock or sugar-maple (*Acer saccharinum*) is a tall ornamental tree, flourishing throughout most of the N. American continent. In sections of the United States where it has not been exterminated, the manufacture of sugar and syrup from it is a remunerative adjunct to other farming industries, occupying a period in which little other farm work can be pursued. The apparatus for collecting the sap and manufacturing the sugar, involves a very small investment; the fuel consumed usually consists of the prunings of the maple grove, which is benefited thereby; and at least 90 per cent. of the gross return is net profit.

An interesting point connected with the production of maple-sugar, is the variability of the flow of the sap, dependent on diurnal changes of weather. The rising of sweet sap commences immediately after the first break-up of the long frost, about mid-February, continuing through March and into April, but varying in different localities and at different seasons. A cold N.-W. wind, with frosty nights and sunny days in alternation, tends to incite the flow, which is more abundant in the day than at night. It is, however, most sensitive to unfavourable changes, and a run of 3 gal. a day from one tree may almost cease in a few hours, and then gradually recover itself. Hence the yield from day to day is uncertain, and reliable statistics are difficult to record. A continuous course of favourable weather tends to the largest production, a rising and falling supply reducing the total of the season. The flow commences earliest in warm and low situations. A thawing night is said to promote it; it ceases during S. winds and at the approach of a storm. On the S. and E. sides, it has been noticed to be earlier than on the N. and W. sides of the same tree. There are generally 10–15 good "sap days" in the season, which continues on and off for about 6 weeks; after this, as the foliage develops, the saccharine matter is reduced, and the sap is said to be "sour," though a restricted flow still continues. Emerson considers that the sugar-yield depends also on the character of the previous summer, and that plentiful rain and sunshine prepare for an abundant harvest in the succeeding spring. Open winters are thought to render the sap sweetest; while much freezing and thawing make it most abundant and of the best quality. The sap of isolated trees is richer in sugar than that of those which are massed together in the forest.

The produce of sugar may average 1 lb. to 4½–5 gal. of sap, but instances are given of 1 lb. of sugar from 3 gal. of sap. In a good sap season, an average tree will run as much as 3 gal. of sap in a day, occasionally more, and afford about 4 lb. of sugar in the season; Emerson records cases of 10, 20, 33, and 43 lb. of sugar from single trees, but such weights are altogether exceptional. The average quantity of sap per tree would be 12–24 gal. in a season. Trees under 25 years old are seldom tapped, scarcely paying for the trouble, apart from the debility it produces in them. Repeated tapping of mature trees causes no apparent injurious effect: in many instances, trees have been tapped for 40 consecutive years, and it is said that both the quality and quantity of sap are visibly improved after the first tapping.

The trees are usually tapped at a height of 3–4 ft. from the ground, with a ¾-in. auger to a depth of 2–6 in., into which a perforated plug is driven, to lead the sap into the collecting-vessels, or a simple notch 1½ in. deep is cut with the axe. One to three taps are inserted in each tree, and have to be removed in succeeding years to fresh places, generally alternated on opposite sides of the tree. In the United States, the large branches are punctured, as well as the trunk. The sap is evaporated either in iron caldrons, or in shallow boilers, 6 ft. long, 2½ ft. wide, and about 8 in. deep. Those of copper are preferred to iron, as they are said to yield a whiter sugar. Care is taken to keep the boilers filled up with fresh additions of sap during evaporation, and to stir it well with a wooden spade, till the syrup attains a sufficiently thick consistency (which is ascertained by its "breaking" or crystallizing when dropped into cold water), and exchanges its white colour for golden-yellow. It is strained during evaporation, a small quantity of lime or soda being added to neutralize any free acids that are present, and a little white of egg or milk to clear it. After straining and skimming, it is poured into pans or moulds to crystallize, and may be further clarified by gently boiling in tapering cans, with a tap at the bottom, towards which the molasses gravitates, and is drawn off as the crystallized sugar sets. Earthenware pots are said to improve the colour but injure the quality.

Many improvements have been made in the manufacture during the last few years. Formerly the highest attainments only resulted in a fine muscovado-like sugar; but now, specimens are exhibited vying with the best loaf-sugar. This has been effected by greater cleanliness in the preparation of the sap, and improvements in draining and refining the sugar. A few years ago, a premium was awarded by the Oswego County Agric. Soc., New York, to R. Tinkor, for the following method of preparing maple-sugar. The sap is boiled in a potash-caldron to a thick syrup, strained while warm, let stand for 24 hours to settle, then poured off, leaving back all that is impure. To clarify 50 lb., 1 qt. of milk, 1 oz. of saleratus, and the whites of two eggs are well mixed; the sugar is then boiled again, until it is hard enough to lay upon a saucer, and finally allowed to stand and cool. Very little stirring will prevent it caking in the caldron. For draining, a funnel-shaped tube, 15 in. sq. at the top, and coming to a point at the bottom, is used. The sugar is put in when cold; a tap is inserted at the bottom, and a damp flannel cloth of two or three thicknesses is kept on the top of the mass. When drained, the sugar is dissolved in pure warm water, and clarified and drained as before.

Maple-sugar is made mostly for the home use of the producers, and as an article of merchandise it seems in a fair way of extinction. Thousands of splendid trees are yearly cut down and converted into broom-handles; and at the present rate of destruction, maple-sugar will before long be unknown in the trade. The amount of maple-sugar made in the States is reported at 40 million lb. annually, but this is considered to be ⅓ below the actual quantity. According to the last census returns, Vermont reported a yield of almost 10 million lb. The production of New York is somewhat larger, but nothing compared with the difference in area; in 1860, there were in this State about 10 million acres planted with sugar-maples at the rate of 30 to the acre. The only other States which return more than 1 million lb. are:—Michigan, 4; Ohio, 3¼; Pennsylvania, nearly 3; New Hampshire, 2¼; Indiana, 1½; Massachusetts, 1. The total production of maple-molasses is 1,500,000 gal., of which, Ohio returns nearly 400,000; Indiana, nearly 300,000; Kentucky, 140,000; and Vermont only 16,000. In addition to the large production of maple-sugar in the States, the estimated quantity made by the Indians living east of the Mississippi is 10 million lb. per annum, and the quantity manufactured by those living west of the river is set down at 20 million, but is probably much greater. The maple-sugar product of Canada was stated in 1849 at 2,303,000 lb. for the Lower Province, and 4,161,000 lb. for Upper Canada. The census of 1851 gave the total at 10,000,000 lb., exclusive of what was used locally without being brought to market. The market value fluctuates between 8 and 22 cents (4-11*d.*) a lb., according to the ruling prices of cane-sugar.

In Nebraska, no maple-sugar is made, but an equally good article is manufactured to a considerable extent from the ash-leaved maple or box elder (*Negundo fraxinifolium*), growing on the banks of rivers from Pennsylvania to Carolina. Some investigations made in Illinois, with reference to its value for sugar, are reported to decide—(1) That it produces more sap than the sugar-maple of equal size, ½ gal. per day being obtained from a small tree of 3½ in. diam. and 5 years old; (2) that the sap is richer in sugar—the yield of dry sugar averaging 2·8 per cent. of the weight of the sap; (3) that the sugar produced is in general whiter than that from sugar-maple treated in the same way. These facts should recommend this tree to the attention of planters, especially in prairie regions.

Melon-sugar.—The preparation of sugar from the melon (*Cucumis Melo*) is fast assuming some importance in America. The long delta between the rivers Sacramento and San Joaquin, California, when reclaimed by embankments, is exceptionally productive. Melons constitute a crop that never fails in this climate, and a factory has been erected on Andros Island to work up the melon-juice derived from a large area at small expense for transport. Water-melons with white pulp are preferred, and it is said that seed obtained from Hungary has yielded plants whose fruits surpassed any produced from native American stock. The plants are set out at distances of 12 ft. apart one way and 6 ft. the other. Their leaves cover the ground and kill all weeds before the latter have time to develop. Besides, they form an impenetrable mulching, which keeps the soil moist.

The juice of the melon is asserted to be free from those non-saccharine bodies which make the extraction of beet- and cane-sugars such an expensive matter. On the other hand, the sugar is uncrystallizable, and does not amount to more than 7 per cent. of the weight of the fruit. Usually the juice is only evaporated to such an extent as to afford a syrup, the ordinary yield being 1 gal. of syrup from 8 gal. of juice. The flavour of melon-syrup is said to be much superior to that of common beet-sugar. The cost of production is set down at 5½ cents (2¾*d.*) a lb., as against beet-sugar at 7 cents (3½*d.*). One grower in California made 125 bar. of syrup in a single season several years since. No doubt is felt that melons would thrive luxuriantly in New Jersey, Delaware, and Maryland. The same may be said of all sub-tropical lands possessing a sufficiently damp climate. It must also be remembered that the seeds afford a valuable oil (see p. 1395), and that the pulp and seed-cake are excellent food for cattle.

Milk-Sugar, Lactine, or Lactose (Fr., *Déchet de lait*; Ger., *Schottensand, Zuckersand*).—This is obtained from milk by precipitating the casein with a few drops of dilute sulphuric acid, and filtering and evaporating the liquid. Crystals are deposited, which are purified by re-dissolving and treating with animal charcoal. In Switzerland, considerable quantities of milk-sugar are prepared by evaporating the whey which remains after the separation of the cheese. At Marbach, Canton of Lucerne, Switzerland, half-a-dozen refiners are said to make a handsome income from the manufacture of milk-sugar. The raw material used for the recrystallization comes from the neighbouring Alps, in the cantons of Lucerne, Berne, Schwyz, &c.; a considerable quantity is supplied also by Gruyères. Notwithstanding rises in the price of the raw material, consequent upon the demand, and increased cost of labour and fuel, the manufacture continually expands, and now amounts to 1800–2000 cwts. yearly, with a gross value of about 12,500*l.* The manufacture of the crude sugar is only carried on in the higher mountains, because there the whey cannot be used profitably for fattening swine, which are found chiefly in the valleys; and the wood required for the evaporating process is cheaper in the highlands.

The crude sugar is sent to the manufacturer or refiner in sacks containing 1–2 cwts. It is washed in copper vessels, and dissolved to saturation at the boiling temperature over a fire; the yellow-brown liquor, after straining, is allowed to stand in copper-lined tubs or long troughs to crystallize. The sugar-crystals form in clusters on immersed chips of wood; these are the most pure, and therefore of rather greater commercial value than the milk-sugar in "plates," which is deposited on the sides of the vessels. In 10–14 days, the crystallization is complete, and the milk-sugar has finished growing. The crystals are then washed with cold water, afterwards dried in a caldron over a fire, and packed in casks holding 4–5 cwts. As the crude sugar can only be obtained in summer, the recrystallization is not carried on in winter. The entire manipulation is carried on in a very primitive manner: with a more rational method of working, a whiter and finer quality of sugar could probably be produced. Milk-sugar finds its chief application as a basis for homœopathic medicines, and in infants' foods.

Palm-sugar.—Palm-sugar, often called date-tree sugar, is a product of the juices of many kinds of palm, the most important being the wild date-palm (*Phœnix sylvestris*), which thus gives a name to the whole class. Other species are the palmyra (*Borassus flabelliformis*), (see p. 932); the coco-nut (*Cocos nucifera*), (see pp. 939, 1353, 1383); the gomuti (*Saguerus* [*Arenga*] *saccharifera*), (see pp. 919, 1827); the nipa (*Nipa fruticans*), (see p. 985); and the kittool (*Caryota urens*), (see p. 938). All these are essentially natives of the E. Indies, including India, Ceylon, Siam, the Malay Peninsula, and the E. Archipelago.

The portion of British India particularly occupied by this cultivation extends nearly due E. and W. from Kissengunge, in Kishnagur, to a little beyond Nollchit in the Backergunge district; and N. and S., from the vicinity of Comercolly in the Pubna district, to the borders of the Sunderbunds, thus occupying on the map a surface of about 130 miles long by 80 broad. Its principal districts are Jessore, Furreedpore, and Backergunge, with portions of Nuddeah, Baraset and Pubna; beyond this tract, little or no date-tree sugar is manufactured, although the tree is often cultivated in other districts, and may be occasionally met with in most parts of India.

Here one species only, *Phœnix sylvestris*, is availed of, though many others might be profitably utilized. From *Cocos nucifera*, good *goor* is commonly made in Province Wellesley; and from *Borassus flabelliformis*, throughout Bengal, a saccharine juice is obtained, used for intoxicating purposes (see Beverages—Toddy, pp. 425–6), frequently as a substitute for yeast in making bread, and is said by the natives to yield a sugar of good grain and greyish complexion.

The sugar obtained by the natives of Bengal and Siam from the various species of palm is, on account of the crude way in which it is manufactured, of very inferior quality, and is mainly consumed in the countries where it is grown. The juice of the nipa palm (*Nipa fruticans*) is almost equal in saccharine richness to that extracted from the sugar-cane, with the advantage that it is much cleaner, and contains no colouring matter nor chlorophyll; the vegetable matter being easily precipitated, it gives a liquor as clear as spring-water. This species, flourishing near the sea, or on the edges of brackish pools, takes up a large quantity of salt, which makes its appearance in the juice, in quantity sufficient, in some cases, to give the liquor a decidedly saline taste. Were it not for this drawback, a large quantity of excellent sugar would be obtained from this source.

The date-palm (*Phœnix sylvestris*) requires a humid soil and climate, and flourishes best in the vicinity of water, though it must be above the reach of annual inundations from the rivers. The trees are planted by the natives mostly in the hedges surrounding the fields appropriated to rice and other grain. Where regular plantations have been attempted, the trees are placed 10–15 ft. apart, so that sufficient space is left for cultivating an oil-seed or other dry crop between them, without its being injured by the shade of their leaves; indigo is said to be the only crop which suffers through not obtaining the full benefit of the sun's rays.

As the modes of planting the tree, extracting the juice, and boiling down into *goor* differ but in trifling details throughout the date-tree tract, a description of the routine practised in the principal district, Jessore, will serve for the whole.

Planting.—The trees are always raised from seed. The fruit ripening in June–July, the seeds are collected and sown shortly afterwards a few inches apart, in a moist spot near the cultivator's house. They are weeded and watered occasionally during the following dry season, and are ready for planting out in the succeeding April–May, after the first showers of the season. The ground is well ploughed, and without any manure, the plants are placed each in a hole made with the hoe or *kodaul*. By the time the rainy season closes, about the following October, they are strong young trees, the leaves 3–4 ft. high; vacancies are then filled up. The roots are occasionally cleared of weeds; and should the ground not be in yearly crop, a ploughing is sometimes given, as this loosens the earth around them and allows more scope for the roots. No other expense or trouble is incurred in their cultivation. The trees arrive at full growth at about their 7th year, but the native cultivator seldom allows them to reach beyond 5 years, before commencing to extract the juice; should the young trees be forward, he even commences at 2 or 3 years old, though this early exhaustion injures the after-productiveness of the plant, and probably shortens its life. Frequently the trees are tapped when the stem is less than 1 ft. high from the ground, a hole being dug in which to lodge the earthen pot that collects the juice. When not weakened by too early tapping, the average age the trees arrive at is about 30 years, being 25 years for sugar production after allowing the first 5 for their undisturbed development. On the borders of the Sunderbunds, however, where the trees grow in strong marshy soils impregnated with salt, it is said that their excessive vegetation causes them to exhaust their strength sooner, and that their age in such places does not exceed 17–18 years.

The quantity of juice obtained before the trees have reached their 5th year is small and uncertain; if allowed their full 5 years for growth, and first cut in their 6th year, the juice for that year is found to be yielded in the proportion of about one-half the yield of a tree of full maturity; in the 7th year, three-fourths of the full quantity; and it is not until the 8th year that the tree is found to give its full average yield of juice.

The natives reckon a *beegah* to contain 160 trees, or two *puns* of 80 each, planted about 10 ft. apart; then the cost may be estimated thus:—

				R.	A.	P.	
160 plant-trees, sowing, watering, &c.				1	0	0	
Planting, and filling up vacancies				1	0	0	
Half-yearly* rent of 1 *beegah* of ground at 2 Rs	1	0	0				
Ploughing twice per annum, at 2 annas	0	4	0				
Weeding ditto ditto, at 4 annas	0	8	0				
Yearly expense	1	12	0				
Which, for 5 years, is				8	12	0	
				10	12	0	(21*s.* 6*d.*)
Add compound interest on the yearly account, at 25 per cent. per annum				10	7	2	
Nett cost of 1 *beegah* of trees ready for producing R.				21	3	2	(42*s.* 4¾*d.*)

* The other half being chargeable on the other crop grown between the trees.

Cutting the Trees and Collecting the Juice.—The trees are first cut about the 20th October. This is done by stripping off the lower leaves of the branching head of the tree on one side, so as to leave a denuded space 1 ft. long; from this, a piece of the bark is removed in the shape of a triangle, each side of which is about 8 in. long, and having one angle pointed downwards. For the next 8–10 days, the cut part is left to harden, and what little sap exudes from it is allowed to run to waste, as not being sufficient for use. Collecting the juice, therefore, does not commence before about the 1st November, a few days earlier or later, according to the season, the first cold nights causing the sap to run freely. As soon as this is observed by the *gauchea* or date-tree labourer, he ascends the tree in the evening, and slices away a further portion, cutting deeper this time, so as to divide the sap-vessels, and from the centre of the triangle towards its sides, in such a way that along the latter a sort of channel is formed, which conducts the juice to the lower point of the triangle; here in a notch is inserted one end of a piece of reed or grooved stick, about 6 in. long, its other end hanging over the earthen pot which is suspended by a string close under it, and into which the juice trickles as it flows from the tree. The instrument used for cutting the trees is a *daw* or billhook, of peculiar shape.

A man having less than 80 trees lets them out, at a yearly rent for their use, to a neighbour who has more, as they would not yield sufficient juice to compensate for the expense of the necessary arrangements. The number worked by any one ryot or family varies from 80 to 300–400; but for facility of calculating the expense, a farm of 160 may be assumed, all full-grown, and capable of yielding the average quantity of juice. Whatever the number of trees, they are lotted off into 7 equal divisions. The trees of one division are cut every evening in succession, so that the whole are cut regularly once in 7 days. The first division may be taken as containing 23 trees, on which the work proceeds as follows. The *gauchea* having cut this number, and suspended the pots on the previous evening, obtains in the morning, as their 1st day's produce, an average of 10 *seers* (of 2 lb. 1 oz.) of juice from each tree; on the 2nd morning, 4 *seers*; and on the 3rd, 2 *seers*; after this, the reed and pot are removed, and for the 4th, 5th, 6th and 7th days, the trees are left to recover themselves, the little juice that still exudes being allowed to run to waste, as not worth the labour of collecting. On the evening of the 7th day, these 23 trees are again cut; this is done by peeling off a further portion from the already open cutting, which again divides the sap-vessels, and the juice recommences flowing; and the same process is repeated throughout the season. Thus the ryot by newly cutting a $\frac{1}{7}$ division of his trees every evening, will have every morning to gather the juice from 3 divisions, yielding respectively 10, 4, and 2 *seers* of juice from each tree; by this system, a uniform quantity of juice is daily procured, and the labour is equally distributed over the time given for it. The ryot having 160 trees would collect daily the juice of 68 or 69, yielding juice as follows:—

	M.	S.
23 trees first day's runnings, at 10 seers each	5	30
23 „ second „ „ 4 „	2	12
23 „ third „ „ 2 „	1	6
Total juice per diem from 69 trees	9	8 (758 lb.)

This refers only to the juice exuding during the night, and collected early in the morning, from which alone sugar is made. It is sometimes customary, with trees which bear well, to collect what may run from them during the day; but as rapid fermentation takes place soon after sunrise, the day-juice is unfitted for crystallization into *goor*, and is boiled up only for sale as molasses. This practice, however, is far from general, and, at the ordinary market rate for molasses, barely repays the labour required. The *gauchea* commences collecting the juice a little before daybreak; as soon as a sufficient number of pots are collected to commence a boiling, they are carried to the boiling-hut. The emptied pots from the trees are ranged on the ground in rows of about 20 each, with their mouths downwards over a layer of straw or dry leaves; the latter is then set fire to, and gives the pots a thorough smoking, covering their inner surface with an even black coat. The object of this is to prevent acidity, which would set up fermentation in the fresh juice, were any of that from the previous night allowed to taint the vessel, but which is neutralized by the alkaline salts contained in the smoke. As an additional slice is pared from the face of the incisions in the trees once every 7th day, this forms towards the end of the season a very deep notch, reaching sometimes nearly half through the trunk. Each succeeding year the trees are cut on opposite sides, so that they have, when a few years old, a deformed zigzag appearance.

Boiling the Juice.—This is conducted in 4 shallow earthen pans, about 2 ft. diam. and 1 ft. deep, set in a square furnace, formed by digging a hole in the ground, and raising a mud structure over it, about 6 ft. sq., in the dome of which are cut the 4 holes in which the pans are set. A hole on one side for feeding the fire, and on the other for the escape of the smoke, completes the arrangement of the furnace; over this, a light roof is usually thrown, supported by bamboos, and thatched with the dried leaves of the date-tree, as a partial shelter from the sun and rain, though the latter is unusual during the season when the work is in progress. The fuel used is the *soondry* wood, with which the date districts are all more or less easily supplied from the neighbouring Sunderbunds, assisted by the dried leaves of the date-tree itself.

The 4 pans are kept about half-full of date-juice, and as the contents diminish by evaporation, fresh juice is supplied, until each is sufficiently filled to complete the boiling into *goor* without further addition. Up to this point, skimming goes on, and the small end of a date-tree leaf is kept floating in each pan, as it is believed to assist the clarification, though probably a mere fancy. No lime nor other alkali is used: the juice is simply boiled until it arrives at its proper granulating consistency, which is known to the natives by long practice, from the appearance of its tenacity when allowed to drop from the end of a stick, and from its colour and appearance while boiling. The juice, as brought from the trees, is clean, white, and transparent, resembling that of the coconut, both in appearance and taste, though much sweeter. These qualities give it a decided advantage over the juice of the sugar-cane, it being quite uncontaminated with feculencies, the separation of which from cane-juice causes so much trouble. The skimmings from the boiling of date-*goor* are consequently trifling, and probably consist principally of vegetable albumen. They are turned to no useful purpose.

The boiling occupies 5–6 hours with each pan, and as soon as it is complete, the *goor* is ladled into a vessel near. If it is intended for immediate sale to the *moyrah* (sugar-maker), this vessel is a long jar-shaped earthen pot, holding 2 *seers* to ½ *maund*,—the size and form varying much. If the pots are large, they are not filled at once, but the boilings of several days are poured in successively, so that 3, 4, or more pots are filled simultaneously, and contain layers slightly varying in quality, though the average in all is the same. A great deal of *goor* is, however, converted by the ryots themselves into a description of sugar called *naund-dulloah*, in which case the boiling is not carried to so high a point; and this allows it to form a larger crystal, and to part with its molasses more freely. In such case, it is ladled at once from the boiling-pans into a large *naund* (conical-shaped vessel) holding 2–3 *maunds*, and in this it is cured and drained in the simplest possible manner.

Returns.—Dry cold weather is most favourable for the date-juice, both as to its quality and yield; the *goor*-manufacturing season in Bengal extends on the average over 3½ months, from 1st November to 15th February. Little is made earlier than the former date, and such is generally of small grain, and inferior; any made later than mid-February is of soft grain, and contains an undue proportion of molasses. Occasionally the warm weather sets in earlier, and cuts short further *goor*-making, though if there be a good fall of rain, this is followed by a temporary return of cold nights: the *goor* season may then be said to commence anew, and very fair produce is obtained even in the first days of March. The finest yield is in December–January, during the coldest part of the season; and on the whole, the estimate of 3½ months (107 days) is the time occupied by an average season. In estimating the yield of good *goor* for a season, ⅕ of the total should be deducted for the diminution caused by unpropitious weather. Thus, 160 trees yielding 9 *maunds* 8 *seers* of juice per diem throughout the season, multiplied by 107 days, and allowing ⅕ deduction for loss by variations of the weather, leaves bazar *mds.* 787–20–13 (56,964 lb.) as the nett produce in juice for the season, and this, divided over 160 trees, gives *mds.* 4–36–4 (356 lb.) as the average total produce of juice from each tree. The proportion of *goor* obtained from date-juice averages $\frac{1}{10}$ by weight, and the density of the latter does not appear to vary nearly so much as that of cane-juice. At this average, the yield by the above calculation from 160 trees would be bazar *mds.* 78–30 (5702 lb.) of *goor*, or nearly 19¾ *seers* from each tree, or 49 *maunds* 8¾ *seers* (3554 lb.) per 100 trees per annum.

The expense of extracting and collecting the juice, and converting it into *goor*, is calculated as follows:—

	R.	A.	P.
Cultivating 160 trees on 1 *beegah* of ground, as before calculated, = R. 21-3-2; assuming these trees to be in full bearing for the average 20 years, the expense per annum is	1	0	11
Half the annual rent, at R. 2 per *beegah*	1	0	0
Labour of collecting and boiling the juice; 2 *gaucheas* at R. 3 per month each, and one headman at R. 4 to boil the *goor*, can fully manage 200 trees, on which their wages for 3½ months will amount to R. 35; for 160 trees	28	0	0
Earthen pots for holding *goor*, say 296, of 10 *seers* each, and costing 12 *annas* per 100	2	3	6
Earthen pans for boiling, extra jars, &c.	6	0	0
Soondry wood fuel (in addition to dried date-tree leaves) for boiling *goor*, 400 *mds.* at R. 5 per 100 *mds.*	20	0	0
Knives, ropes, and boiling utensils	1	0	0
Setting up furnace and *chopper* roof	1	0	0
	60	4	5
Deduct value of *soondry* wood charcoal from the furnace	1	0	0
Nett cost of 78¾ bazar *mds.* (5645 lb.) of *goor* at the average rate of 12 *annas* (1*s.* 6*d.*) per *maund*	59	4	5 (5*l.* 18*s.* 6½*d.*)

From an estimate of the quantities of palm-sugar purchased for European refineries, added to the native refined sorts sold for export in the Calcutta market, under the names of *gurputta* and *dobarrah*, Robinson concluded that 9500–10,000 tons, or at least ⅕ of the whole annual quantity of sugar exported to England from India was in 1850 composed of palm-sugars. The attention bestowed by Europeans on the production of these sugars for the Calcutta or home markets, has been confined to the remanufacture or refining of the native raw material (*khaur*, *dulloah*, &c.); for this purpose, it is held in great esteem, producing a good-coloured and well-crystallized sugar, and yielding a greater percentage in weight of refined goods than can be obtained of equal quality from the same weight and class of cane-sugars. On the other hand, raw palm-sugars are more liable to deteriorate by being kept in store, losing both colour and strength rapidly; this applies, however, to the raw products only, the refined or reboiled sugars bearing transport and storage as well as those from cane.

The cause of these peculiarities appears to lie in the larger proportion of gluten present in palm-sugars; they are no less remarkable in the molasses than in the sugar itself, that from palm-sugar possessing far less saccharine matter, and being of much darker colour than that from cane, which is probably caused by the gluten being partly decomposed by the lime and heat of the boiling process. Another distinguishing feature is the absence from palm-sugar of the empyreumatic oil observable in the cane product, and which gives to rum its well-known flavour.

Considering the low cost of palm-sugars, and the little trouble and risk incurred in rearing the trees, it seems at first glance remarkable that European planters have not entered upon this cultivation for producing sugar on a large scale. But discouragements no doubt exist in the nature of land-tenure in Bengal, the length of time the trees occupy in coming to full bearing, and the difficulty of collecting the juice for boiling into sugar by the European method after they have been reared. It has been shown that the annual produce of a full-grown plantation is equal to 78⅜ *maunds* of *goor* per Bengal *beegah*, which, converted into *khaur*, may be taken as equivalent to about 5½ tons of muscovado sugar per acre.

Sorghum- and Maize-sugar.—The saccharine value of the graminaceous plants known as N. China cane, Guinea corn, millet, durra, imphee, sorgo, &c. (chiefly *Sorghum saccharatum*, *S. vulgare*, and *S. caffrorum*), has for ages been recognized in Africa and China; and it would seem that sugar was extracted from maize (*Zea Mays*) by the ancient Mexicans. Of late years, new attention has been attracted to these plants as sugar-producers, principally in the United States, but also in Canada, Australasia, India, England, and France.

Qualities.—The cultivation of sorghum, maize, and pearl-millet, and the manufacture of sugar from their stalks. were made the subject of extensive experiments by the U. S. Department of Agriculture, during 1879, and again since. The investigations demonstrate little difference between the various kinds of sorghum as sugar-producers ; and seem to prove that each of them is, at a certain period, nearly as rich in sugar as the best sugar-cane. This maximum content of sugar is maintained too for a long period, and affords time to work up a large crop.

The varieties grown and investigated were Early Amber, White Liberian, Chinese, and Honduras sorghums, and pearl-millet. The analyses of each of the plants in successive stages showed that the uncrystallizable sugar diminishes as the true sugar increases. They differ widely in the date when the crystallizable sugar is at its maximum, but are alike in that it is attained at about the same degree of development, viz. at full maturity, as indicated by the hard dry seed, and the appearance of offshoots from the upper joints of the stalk. Analyses of several sorghums after they had been subjected to a very hard frost, sufficient to form ice ½ in. thick, and continued for 4 days, exhibited no diminution of crystallizable sugar, and no increase of uncrystallizable; but the influence of the subsequent thaw was noticeable in the diminution of crystallizable and increase of uncrystallizable sugar. Thus it would appear that protracted cold is not injurious to the quality of the canes, but that they should be worked up before they have thawed.

The Early Amber, Chinese, Liberian, and Honduras sorghums, and the pearl-millet, were planted on the same day, May 15, 1879. The relative weights of the different kinds of stalk are:—Early Amber, average of 40, 1·73 lb.; White Liberian, average of 38, 1·80; Chinese, average of 23, 2·00 ; Honduras, average of 16, 3·64.

These were grown side by side on land of equal fertility, and afford data for calculating the average yield of each per acre. Early Amber and Liberian closely correspond in their development. While these two attain a sugar-yield equal to average sugar-cane by mid-August, the Chinese does not reach this condition until late September, and the Honduras not until mid-October. An average of all the examinations of the four sorghums during the periods when they were suitable for cutting gives the following results :—Early Amber, Aug. 13–Oct. 29 inclusive, 14·6 per cent. crystallizable sugar; Liberian, Aug. 13–Oct. 29, 13·8 per cent.; Chinese, Sept. 13–Oct. 29, 13·8 per cent.; Honduras, Oct. 14–29, 14·6 per cent.

Varieties.—The Department now has 30–40 varieties of sugar-producing sorghums, all valuable to a greater or less degree, according to the soil, climate, cultivation, seasons, and process of manufacture. Other useful varieties are doubtless to be obtained. The so-called "Honduras" sorghum is only one of the kinds indigenous to Honduras; and there are probably several varieties growing in Central America, and even as far south as the Rio de la Plata in S. America. Early Amber is the favourite variety with planters in Minnesota and the N.-W. Minnesota Early Amber is claimed as an improvement upon the Early Amber, obtained from selected seed sent to a more southern latitude to be grown and then returned to Minnesota.

Early Amber receives its name from its early ripening, and from the bright amber colour which characterizes its syrup when properly made. It is very rich in saccharine matter, and when properly treated, its products are devoid of the peculiar "sorghum" taste formerly complained of, the flavour being similar to that of pure honey. The Chinese sorgo is about the same height as the Early Amber. Its seed-heads are fuller and more compact, somewhat resembling a head of sumach, whence the synonym "sumach-cane." White Liberian is rather taller than Early Amber. The stalk curves at the top, leaving the head pendent; hence the synonym "Gooseneck." It is also styled a variety of the White Imphee. The Honduras cane grows about one-half taller than either of the other varieties. Its seed-top is reddish-brown and spreading; hence its name "sprangle-top." It is also called "mastodon" and "honey-cane."

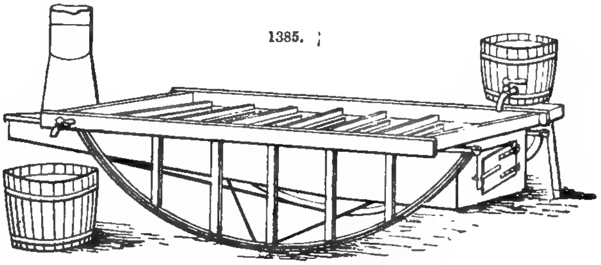
Cultivation.—Soil.—Some cultivators fear that new land imparts a strong flavour to the syrup. Others say that old land produces a syrup of brighter colour, but not of better flavour. An advantage of new timber land is the small amount of cultivation required. Costly culture on old land will not pay in opposition to cheap culture on new land. New land is comparatively free from foul seed, and consequently less liable to weeds. If it is necessary to clear old land of weeds, or to fertilize it with farmyard manure, a crop of corn should first be grown on it. General opinion is in favour of a sandy, upland soil, well drained, but not freshly manured. Manuring spoils the flavour of the syrup. The majority of cultivators are in favour of indefinite repetition of the crop on the same soil. Some have cultivated the same ground for 7 years without deterioration, the product ranging from 250 to 300 gal. of syrup per acre. The soil is not required to be very rich. Land too poor for wheat has given 200 gal. per acre of excellent syrup.

Preparation of the Ground.—Fall (autumn) ploughing, putting the plough to the beam, causes all foul seed, and especially pigeon-grass, to germinate in the fall, and be killed in winter. Another advantage is that the crop is less liable to injury from droughts in the early season. A large crop can be raised the first year on open prairie and at the first breakage, especially if the La Dow harrow be used. When the ground becomes sufficiently warm in the spring, some go over it with a Beaver Dam seeder, and then with a drag and roller. This treatment effectually disposes of the grass, generally considered of first importance.

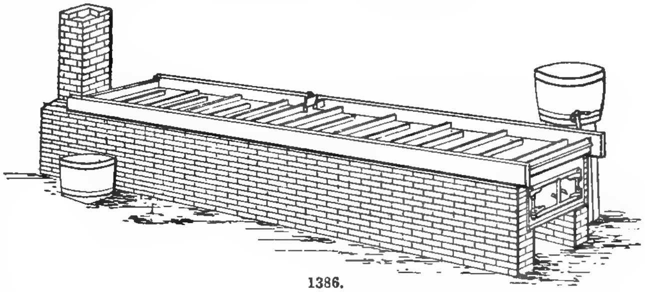
Time of Planting.—The cane should be planted as early as it is possible to work the ground properly, avoiding late frosts. The ground should be well warm before the seed is put in. In Minnesota, the average seeding-time is early May; it should not be quite so early on ground impregnated with grass-seed. If postponed till the season is warm enough to germinate the seed quickly, better results may be got, as a late spring frost may cut down early plants, and, before they grow again, pigeon-grass is apt to start up profusely.

Seed.—By steeping the seed in warm water for 24–48 hours, it becomes sprouted, and grows more rapidly; but a dry season will kill the sprouted seed, and the crop will be a failure. Seed brought from the latitude of St. Louis is in great favour. Some Minnesota growers send their seed to Missouri and Kansas to have a crop grown and its seed returned. Seed imported from S. Indiana produced, on its first sowing, stalks 12–15 ft. high; but by planting the seeds of each crop, its successor showed a declining height, until it was but 7–8 ft. The sugar-yield also diminishes. The deterioration of the seed is generally not very marked till the third year. Southern seed excels less in an earlier ripening of the crop, than in increased product, in some cases amounting to one-third. The seed has a value of its own for feeding hogs, sheep, and poultry.

1385.



Planting. — Planting must be deep enough to secure moisture, hence, early plantings should be shallower than late ones. Some growers plant in rows 3–3½ ft. each way, and use 2 lb. of seed per acre, or 6–7 seeds to the hill, thinning out at the second hoeing. Seed should not be planted in the trough of the marking furrow, where heavy rain is apt to wash it away, but on the edge. Others plant at 15–18 in. one way and 3 ft. the other, the rows running north and south. A tract of 4 acres sown broadcast produced at the rate of 450 gal. per acre. Many planters practise stepping upon the seed as placed in the ground, urging that the close pressure of the soil around the seed enables it to germinate more rapidly. Stepping the seed causes the ground to bake, if it is wet clay.



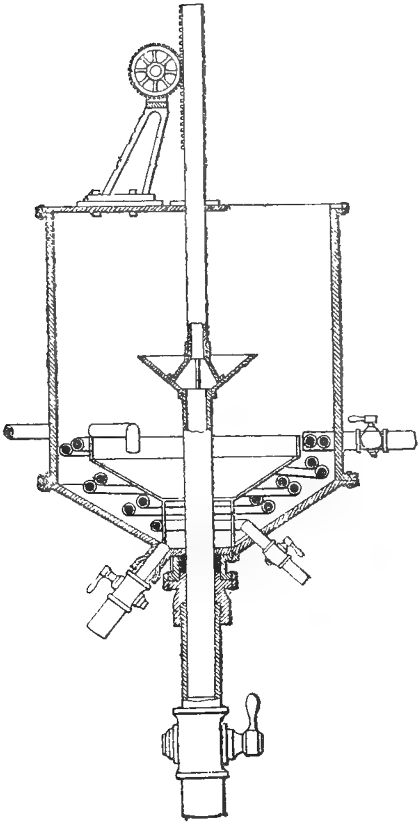
1386.

Culture.—The leading point presented in the culture is keeping clear of weeds. This requires prompt action with the hoe, drag, and cultivator. The plants are too tender for Thomas's harrow. The crop should be thoroughly hoed, until large enough to cultivate with the plough or cultivator.

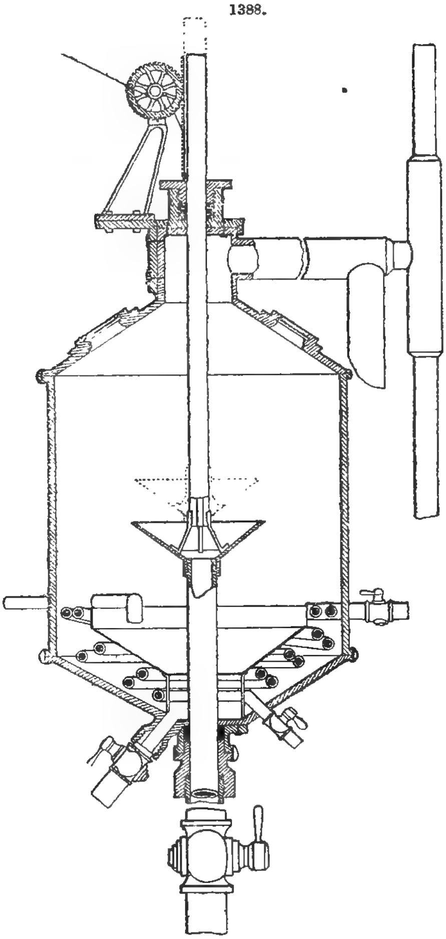
Time to Cut the Cane.—The best results may be got from early cuttings, if there is a risk that extremely hot weather will invert the crystallizable sugar. The proper time is when the seed is in the "stiff dough," or from Aug. 28 to Sept. 1. The juice seems to improve for a few days, but afterwards it begins to decline in saccharine matter. The earlier the cutting after the seed has reached the dough stage, the larger the product, and the brighter and cleaner the syrup.

Harvesting.—With regard to stripping off the leaves, it is urged that if the leaves are put through the mill with the stalk, they absorb a large portion of the juice, but this should not be the case with mills of sufficient power. The cost of stripping the leaves before cutting is estimated at $15 (3*l.*) per acre, and it would not pay unless labour were plentiful and cheap. The Agriculture Department experiments show little or no difference between stripped and unstripped cane, although the mill used was an indifferent one. The cane should be cut, some say, at 6–8 in. from the ground, and others, at the first joint. The top should also be cut off at 18 in.–2 ft. Some planters lay the cane in windrows, and others oppose the practice, as exposing the leaves, if not the stalks, to mildew. Some insist that cut cane should be immediately placed under cover, to avoid evaporation by the sun; others pile in ridges 4 ft. high, and cover the mass with marsh hay, laying poles along the piles every 2 ft., in order to admit fresh air; others again pile it as sugar-cane is sometimes piled in the field, crossing the hills in such a way as to secure ventilation, and shed the rain. Crops kept in these different ways for several weeks are reported to have produced large and fine syrup returns.

1387.



1388.

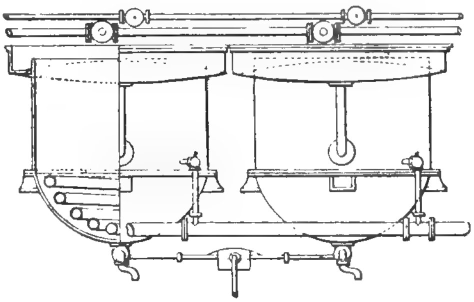


Transport to the Mill.—It is best for the farmer to manufacture the cane as well as raise it. In moving the cane from the field, there is much to be said in favour of bundling it. Some decapitate it with a broad axe, after binding. The points to be kept in view, both in the transportation and in the storing of the cane, are protection from the weather, and such ventilation through the mass as will prevent mildew.

Manufacture.—The extraction of the juice from sorghum-stalks, and its conversion into sugar, is almost an exact repetition of the operations connected with the manufacture of cane-sugar (see pp. 1860–1902). The machinery and apparatus are identical in principle and purpose, but are usually constructed on a much smaller scale, as well as being often of a portable nature.

Crushing-mills.—The Victor mill, made by the Blymyer Company, Cincinnati, is in very common use in the United States. It is arranged either vertically or horizontally, and is adapted to all kinds of motor. There are 7 sizes. The smallest requires 1 H.P., gives 40 gal. of juice per hour, weighs 395 lb., and costs about 10*l.*; the largest takes 4 H.P., runs 170 gal. per hour, weighs 1900 lb., and costs about 46*l.*

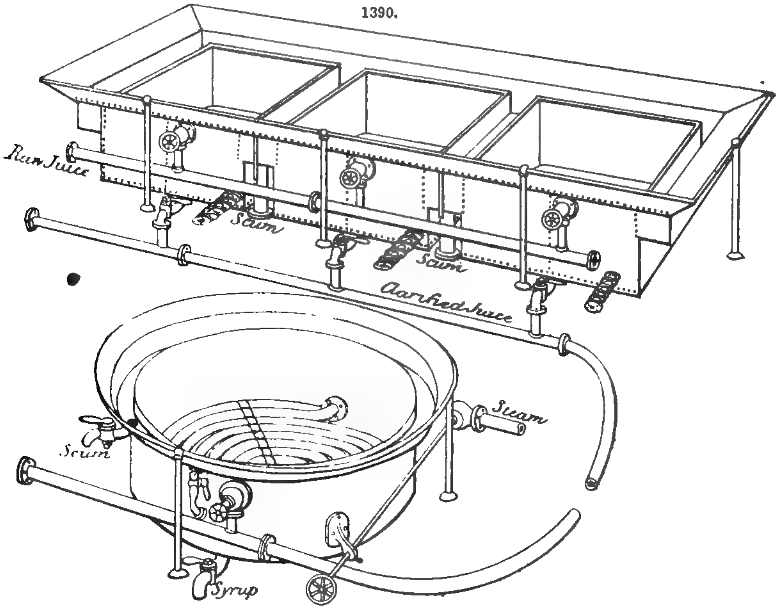
1389.



Evaporators.—Figs. 1385, 1386, show respectively a portable and stationary Cook evaporator made by the same firm. The former consists of pans 44 in. wide, and 6–9 ft. long, ranging in capacity from 40 to 90 gal. a day. When the pans are of galvanized iron, they cost 13–17*l.*; when of copper, 11–14*l.* more. Each contains a portable furnace. The whole can be lifted into a wagon by two men, and conveyed thus from field to field. The stationary evaporators are made in 7 sizes, 44 in. wide, and 6–15 ft. long. With a capacity of 40–180 gal. a day, the prices are 6–18*l.* for galvanized iron, and 16–42*l.* for copper.

Fig. 1387 shows McDowell's evaporator, 6 ft. diam. and 2 ft. deep. It is furnished with steam-coils 125 ft. long, and a diaphragm directing the currents of evolution over the steam-coils, up the outside, and down the middle axis. In the centre, is an adjustable funnel-shaped skimmer, which can be raised or lowered to the level of the boiling juice. It catches the scum, and delivers it by a pipe through the bottom of the evaporator. Two evaporators will reduce 600 gal. of defecated juice by one-half in 1½ hours.

1390.



McDowell's concentrator, Fig. 1388, differs in having a closed top and a water-jet condenser, producing a vacuum. In this, 600 gal. of evaporator-juice are reduced to 200. The product is then "semi-syrup," and can be stored, or shipped to a refinery, or further reduced in a vacuum-pan.

Fig. 1389 is a direct steam evaporator, which boils clarified juice by means of a steam-coil, the scum passing over into the trough around the upper edge.

Fig. 1390 is a steam-train, made at the Colwell Iron Works, New York. It consists of 3 clarifiers, and an evaporator, requires little labour, dispenses with pumps and ladles, and finishes the syrup up to the vacuum-pan.

Fig. 1391 is a cheap home-made evaporator, which can be put together by an ordinary mechanic. It is constructed by putting wooden sides and ends upon a galvanized iron or copper tray.

1391.

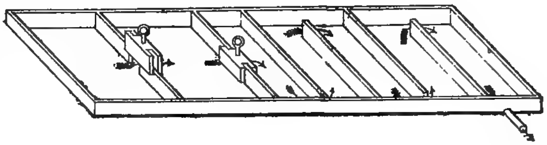


Fig. 1392 shows Stubb's evaporator. The first compartment occupies ¾ of the whole pan, leaving ¼ for the second. The juice enters the first compartment near the smoke-stack in a regular stream, passing around the semi-circle over the fire-box to cross-partitions, where it thickens to a semi-syrup. Being over the hottest part of the furnace, it rises to a light foam, which breaks to the lowest point where the cool juice enters, not only keeping back the green scum, but carrying all the scum off 30 ft. of surface, where it is scraped off without loss of sugar. The semi-syrup is turned into the second compartment at intervals, to be finished under full control of heat governed by dampers.

Defecators.—Fig. 1393 is McDowell's defecating-tank, 8 ft. long, 5 ft. wide, and 2 ft. deep. The bottom is covered with a steam-coil, and contains a strainer, through which the clear juice can be drawn. Each tankful can be treated in 30 minutes. Two of these tanks suffice to defecate 600 gal. per hour.

1392.

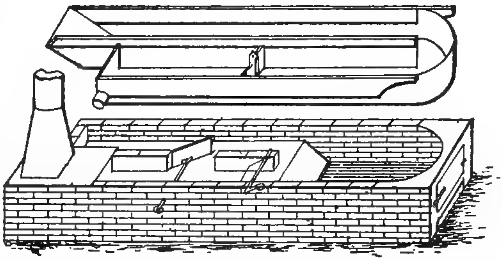
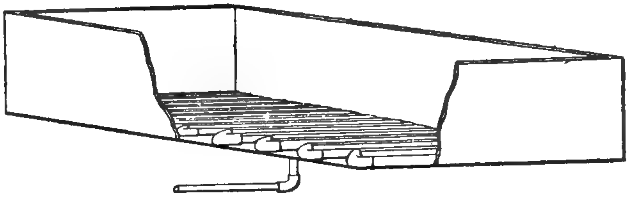


Fig. 1394 represents the apparatus required in F. L. Stewart's process: a defecating-tank D, a short 10-gal. cask C, a lacquered funnel F with indiarubber ring around the neck, a plug *r* for thrusting into the throat of P, and a piece of indiarubber piping R. Directions for its use are as follows:—Place the cask on a bench nearly level with D. Pour 1 gal. of water into the cask, then pour ½ gal. sulphuric acid into a wooden bucket, allow it to flow thence into the cask, and well mix it. Next insert the rubber-covered neck of the funnel tightly into the larger hole in the head of the cask. Compress one end of the long tube slightly, and insert it in the smaller hole. Insert the plug with the rubber ring around it in the throat of the funnel closely, and it will be air-tight. This is then ready to work, as indicated in section 6.

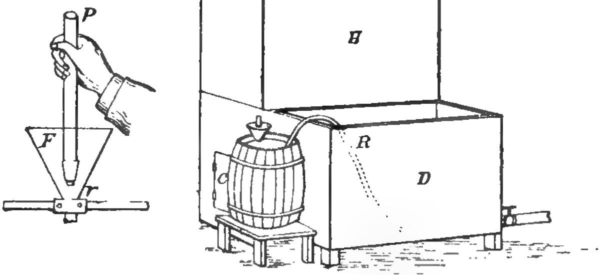
Some of Stewart's patent powder is dropped quickly, 1 lb. at a time, through the funnel into the cask containing the diluted acid, the plug is quickly inserted, and immediately sulphurous oxide escapes through the tube into the clear juice in the tank D; 1 lb. of powder is usually sufficient for 150 gal. of juice when its gas is all discharged. The juice must absorb the gas until it becomes acid. Never allow the cask to get more than half-full of the mixture, or the sulphuric acid may foam over into the juice and decompose some of the sugar. Lift the end of the rubber tube out of the tank when the gas ceases to flow, or the juice may be forced back into the cask. In factories where 1000 gal. of juice are run into the defecating-tank at once, a 40- or 50-gal. cask should be used. The sulphuric acid is neutralized when about an equal weight of the powder has been dropped in; therefore 1 gal. of acid poured into 2 gal. of water will eliminate the gas from about 14½ lb. of the powder. When this proportion has been reached, or when the gas ceases to flow upon the addition of more powder, empty the contents of the cask, preserving the fine sediment for use as a fertilizer: it is principally sulphate of lime. Rinse out the cask, and go on as before.

The complete operations are:—(1) Heat the freshly-expressed juice in a copper or tinned-iron vessel to 82° (180° F.); (2) stir in gradually milk of lime until the red test-paper turns blue: about 3 pints to 100 gal. of juice is generally needed; (3) heat rapidly to the boiling-point, and then shut off the heat, or remove the vessel from the fire; (4) as soon as the sediment begins to settle, siphon off the clear liquid from near the top into cooling- or defecating-tank, until at least $\frac{9}{10}$ of the juice has been removed, leaving a thick muddy sediment at the bottom; (5) sweep out this muddy sediment with a broom through a large opening at the bottom of the heater, into a smaller vessel below, and rack off any clear juice that afterwards separates from it, and add to the contents of the defecating-tank; (6) into each 150 gal. of this clear and partly cooled juice in the defecating-tank D, introduce as much gas as is produced by operating with 1 lb. of the powder, or until blue litmus-paper is reddened; (7) the juice is run into the evaporator, and boiled rapidly in as shallow a bed as possible, removing any scum that forms: it should continue acid until the close of the boiling; (8) before the syrup has become very dense, it is passed from the evaporator into the finishing-pan. Evaporate here rapidly to a dense syrup, stirring constantly at the last, when a white cloud begins to be seen in it at about 113° (235° F.); turn out into the cooler, and remove to a warm place to crystallize; when cooled to about 38° (100° F.), stir a few grains of sugar in to hasten it.

1393.



1394.

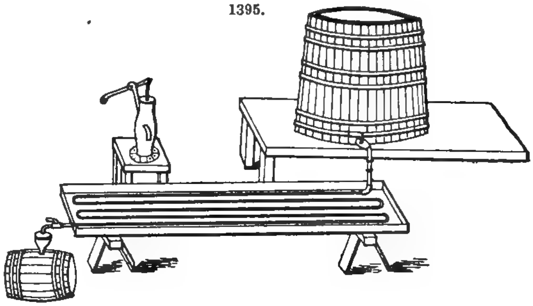


Coolers.—Fig. 1395 shows a very convenient arrangement for cooling syrup.

Complete Factory.—Fig. 1396 illustrates the arrangement of a complete sorghum-sugar factory. The juice, after running from the crushing-mill into a tank on a lower level, is pumped into the juice-tank *a*. *b* is the defecator; *c*, settling-tanks; *d*, supply-tank for evaporator *e*; *f*, supply-tank for strike-pan *g*; *h*, receptacles for scum; *i*, trucks for conveying the syrup to the sugar-room. The cost of such a factory is about 2000*l*. for a small size.

Local Details.—In New South Wales, sorghum has been found to stand frost better than the sugar-cane proper, and is little affected by floods. It comes to maturity in 5 months, and therefore may be employed as an interval crop, alternating with sugar-cane, and keeping the sugar-mills going. In 1868, there were 296 acres planted with sorghum in various districts; but in 1872, this was reduced to 32 acres. Growers expect 1¾–2 tons of sugar to the acre. When not grown for sugar, the plant yields abundance of valuable food for cattle, at the rate of 30–40 tons of cane per acre.

1395.



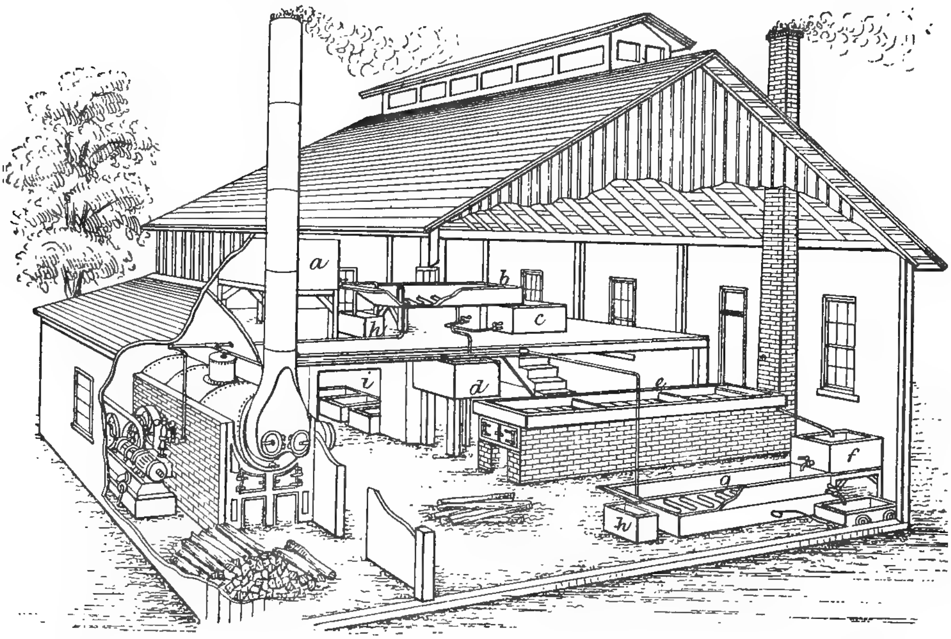
In France, Vilmorin states that it is capable of yielding on an average, from an acre of land, 26,000 lb. of juice, containing 10–13 per cent. of sugar: and that is more than the average yield of the sugar-beet. It is alleged, however, that the plant is adapted to only a few parts of S. France.

Wray asserts that some of the varieties which he introduced from Natal gave 30 cwt. of sugar per acre, and that it has yielded from a poor hand-mill 68 per cent. of juice, containing 15 per cent. of sugar. Where the sugar-cane has yielded 30 cwt., sorghum has given 25, but then there is often a second and a third crop to be obtained within the year. Sorghum can in many localities be advantageously utilized for preparing syrup. For this purpose, the juice is expressed at the time of flowering, and simply evaporated; the yield is about 100 gal. per acre.

Since 1855, its cultivation has steadily increased in many countries. It is grown in France and Algeria, for alcohol chiefly; in Italy for its syrup in wine-making.

In the N.W. States of America, where it flourishes, there were in 1864, 366,670 acres under sorghum, and sorghum-sugar was selling in Chicago at 4½*d.* a lb. In 1860, nearly 7 million gal. of sorghum-syrup were produced in the United States. This had increased in 1870 to 16,050,089 gal., and 24 hhds. of sorghum-sugar were made. In Kansas, there were 23,026 acres under sorghum in 1875. The produce was 2,542,512 gal. of syrup. Sorghum is cultivated to a considerable extent in the Ohio belt of counties, W. Virginia. It is used entirely for the manufacture of syrup for home consumption, where the locality has been more or less denuded of its maple-trees. Most persons prefer the syrup prepared from the maple (see pp. 1902–3) to that from sorghum, as the latter has too commonly an acid taste. The total production for W. Virginia was given in 1876 at 780,829 gal.

1396.



W. Ingram has reported on experimental cultivation of Minnesota Early Amber sorghum, on the Duke of Rutland's estate at Belvoir, in the season 1880. Two sowings were made in April: one within the shelter of a frame, and one in the open ground. In the latter instance, the seed failed to germinate in April, and only a few grains vegetated in May. This was much owing to the ungenial weather. The portion sown in a frame appeared in April, and made rapid and healthy growth. But owing to the subsequent very unfavourable weather, the crop failed to reach the point of maturity indicated by production of seed, and did not attain sufficient ripeness to elaborate the juice in sufficient quantity for experimental manufacture of sugar. It seemed, however, to promise a valuable nutritious food for pigs. The occurrence of severe frost in October completely destroyed the crop, showing that it must be harvested before the end of September, or early enough to secure it from frost. The seed cannot with safety be sown so early as April, and probably the 2nd or 3rd week in May would be early enough; the rows need not be more than 2 ft. apart. The inherent vitality of the plant is encouraging. After being checked and injured by 3 months of cold, wet weather, with the arrival of a little warmth, it speedily regained health, and made active and vigorous growth. In America, the best results have been obtained on light loamy soils, resting on porous subsoil. The plant will bear removal from its seed-bed remarkably well.

Starch-sugar, and other Glucoses.—Under this head, are included the various factitious sugars, syrups, and brewing compounds, obtained by the artificial conversion of starch (see pp. 1821–9) into sugar, and from the refining of cane-sugar.

Formation.—From the theories of different chemists concerning the formation of dextrine (see pp. 1645–7), and the transformation of starch into dextrine and starch-sugar, the following conclusions may be deduced:—(1) Starch torrefied at a temperature not exceeding 180°–200° (356°–392° F.)

is largely transformed into dextrine. (2) Starch heated with diluted acids changes in the first place into soluble starch, and then into dextrine and starch-sugar. The quantity of the sugar formed depends on the concentration of the acids, and increases considerably during the period of its action, while the amount of the dextrine at the same time decreases. (3) Starch heated with a solution of diastase (malt-extract) will likewise at first change into soluble starch, of which the larger part is first turned into dextrine and the lesser into sugar. The quantity of starch-sugar will depend mainly on the temperature under which the diastase operates. A large quantity of sugar is formed at 60°–65° (140°–149° F.); but at increased temperatures, say 65°–75° (149°–167° F.), larger quantities of dextrine are formed, until finally, by continued increase of temperature, the diastase itself is destroyed. (4) Sugar formation increases during the action, by the diminution of the dextrine, especially when the sugar formed is caused to ferment by yeast, and is thereby removed. The quantity of sugar formed but little exceeds that of the dextrine, even in the most favourable cases.

Principles of Manufacture.—Starch-sugar finds no application which mixtures of crystallizable and uncrystallizable sugars cannot fulfil, and is merely a substitute. Hence its manufacture is only advantageous when it can be produced more cheaply than cane- or beet-sugar. The article appearing in commerce is very often far from being pure grape-sugar, and contains upwards of 50 per cent. of water and unfermentable substances. The relative quantity of sulphuric acid used in the transformation is of importance, as the time needed for conversion is dependent upon it. The transformation occurs much more rapidly when 2 than when 1 per cent. of sulphuric acid is added. Boiling under increased pressure also reduces the time of the operation. The sulphuric acid remains unchanged by the process; but a full explanation of its action has not been given. It can be removed from the liquid by carbonate of lime.

According to calculation, every 220 lb. of dry starch should furnish 238 lb. of dry sugar, corresponding to 264 lb. of crystalline starch-sugar, if the transformation were perfect. But complete transformation does not occur until after the lapse of 36 hours, or even longer, when, by the simultaneous action of the sulphuric acid upon the sugar that had been formed many hours previously, large quantities of other products accumulate in the solution. The products of decomposition thus formed constitute a greater evil than the small quantities of dextrine otherwise retained in the finished sugar. Too long boiling of the starch with sulphuric acid produces an entirely useless article. The transformation of starch into dextrine and starch-sugar by diastase (malt) occurs most rapidly and completely at the "mash" temperature of 60°–65° (140°–149° F.). The formation of soluble starch in this case takes place in a very short period. Starch-gum and -sugar are produced simultaneously, and the starch-gum (dextrine) itself cannot be completely transformed into sugar, even by continued action of the diastase; if, to the solution thus obtained, about 1 per cent. of sulphuric acid is added, and then boiled, an approximately complete transformation takes place, especially if the boiling is done under pressure.

These general remarks suggest the following rules for practice:—Pure crystalline starch-sugar can only be produced by means of sulphuric acid and long-continued boiling. A short boiling in sulphuric-acid water produces a glucose containing considerable quantities of an intermediate product between gum and sugar. The sugar thus obtained is not hard and crystalline, but soft and tough, and becomes moist in the air. From a syrup thus produced, no solid sugar separates, because the starch-gum prevents the separation. With a syrup obtained by too long boiling, there ensues a separation of starch-sugar in a grainy condition. This is considered as spoiled glucose. [The term "glucose" in America is reserved for starch-syrup which will not become solid.] Syrup prepared by means of malt alone contains a considerable amount of dextrine. By the application of sulphuric acid, after the use of malt, the dextrine can be transformed in a great measure into sugar. Starch-sugar can be made directly from potatoes, grain, moss, wood, fruits, honey, &c. In the manufacturing industries, it is mainly made from starch; but the manufacture from wood is now being carried on in one factory. In the United States, corn-starch is with but few exceptions employed; in Europe, potato-starch. Quite recently cassava-roots (see Starch—Tapioca, p. 1828) have been used; the yield from an acre of this crop is said to be 20 times as great as that from an equal area of corn.

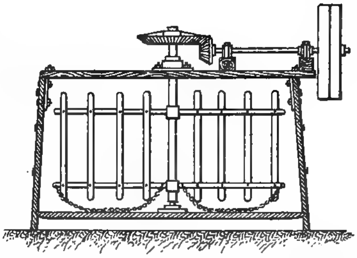
Starch-sugar appears in commerce in 5 different forms, (1) starch-syrup; (2) a sticky mass, termed "imponderable syrup" or "glucose"; (3) granulated sugar; (4) common solid sugar; (5) refined solid starch-sugar, distinguished by its whiteness and sweet flavour, which are secured by refining.

MANUFACTURE.—The manufacture of starch-syrup and starch-sugar by means of sulphuric acid is divided into the following operations:—(1) Boiling the starch in sulphuric-acid water; (2) removal of the sulphuric acid (in the state of sulphate of lime) from the solution; (3) evaporating and refining the sugar solution. These are performed in various ways.

Boiling.—The boiling of the starch in water containing sulphuric acid is best performed in a wooden vessel by direct admission of steam, with, however, the disadvantage of introducing much water. Lining the vessel with lead is not necessary, but increases its durability. Formerly the boiling-vats were constructed in such a manner that they could be heated under pressure; but the starch becomes somewhat thin and liquid, because the steam condenses.

The modern stirring-tub (Fig. 1397) has a spiral copper worm, through which steam circulates. By this means, the mass is brought to a boil without being diluted, so as to show 19°–20° B. when cooked. There is thus a great saving of fuel. The staves for the vat are of good pine, 2½ in. thick. A vat to boil twice a day 3300 lb. of green starch, should be 8¼ ft. high. Its diameter below is 5⅝ ft., and above 5½ ft.; it is open above, with a cover to be laid on, and a chimney. The chimney is square, and made of ⅝-in. pine boards, 10½ in. wide in the clear, and of a height to project above the roof, to carry off the odours. The vat is placed upon a strong framework, so that the boiled starch can run into the neutralizing-coops by means of spigots above the bottom. The copper worm has a diameter of ½ in., so that it may be inserted in the vat without trouble. The rings are fastened with brass clamps. Nothing is made of iron; all screws and nuts are of copper. The condensed steam escapes at the side through a pipe connected with the copper worm and is carried to the condensed-water tank.

1397.



The requisite quantity of water is placed in the vat, and heated to boiling, after the previously diluted sulphuric acid has been added. The starch, mixed with lukewarm water to a milky consistency, is gradually run into the vat from the stirring-tub, while the liquid in the boiling-tub is kept at a constant boil. As the starch deposits quickly from the starch-milk, the solution must be constantly stirred. The larger the quantity of the boiling liquid, the less tendency there will be towards the formation of a paste. If no stirring-vat for the starch-milk is placed over the boiling apparatus, the starch-milk must be poured into the boiling sour water in portions. For each 220 lb. of air-dry starch (holding 10 per cent. of moisture) about 40–55 gal. of water, and generally 4½ lb. of sulphuric acid are used, when syrup is to be produced; for the manufacture of solid sugar, the acid may be increased to 8⅝ lb. The water stated includes that used for stirring the starch. The quantity must at any rate be such that the worm in the converter is covered. As the starch used in glucose-factories is generally prepared there, and as the green starch can be well preserved in vats and barrels, it is generally applied in a moist condition; hence, instead of using 440 lb. of dry starch, a larger quantity of green starch is taken, and the water contained in the green starch is allowed for.

When the entire quantity of starch-milk is in, the boiling is continued until the transformation is accomplished. If syrup is to be produced, the boiling is of shorter duration than for solid sugar. During the boiling of potato-starch, a very disagreeable, penetrating odour is developed. At short intervals, the liquid is tested, first with a solution of iodine, and afterwards with alcohol. For the iodine test, a few drops of the sugar liquid are placed in a test-tube, diluted with cold water, and treated with a few drops of solution of iodine; when the liquid is no longer coloured violet or reddish, the transformation into dextrine and starch-sugar is finished. For the alcohol test: a little of the liquid in a test-tube is added to an equal or double volume of strong alcohol; the stronger the white separation caused thereby, the larger is the quantity of dextrine still present. Even when the precipitation ceases, some dextrine is still unchanged; a ready means for determining its complete transformation into sugar is not yet known.

Neutralization and Filtration.—When the transformation is sufficiently complete, the sulphuric acid is neutralized by the application of carbonate of lime. The acid decomposes the lime, carbonic acid gas escapes, and insoluble sulphate of lime is produced; the liquid loses its acid reaction, and becomes neutral. This operation can be conducted in the boiling apparatus, but, in most cases, is performed in neutralizing-vats. These are flat vessels, whose height stands to their width in the proportion of 1 to 3. The most suitable form of carbonate of lime is chalk, but limestone free from clay can be applied. It is indispensable that it should be in fine powder. A handful of this powder is thrown at a time into the hot, acid liquid, constantly stirred and mixed till no further ebullition ensues. Some manufacturers apply the chalk in bags, whereby the settling and refining are simplified. Each 1 lb. of sulphuric acid contained in the liquid requires 1 lb. of pure carbonate of lime; of chalk or limestone, more must be taken, as they are not pure carbonate of lime. Excess should be avoided, so as not to unnecessarily increase the sediment. As soon as titrations show a perceptible approach to neutrality, the liquid is boiled for a short period before more carbonate is added. The cessation of effervescence is a partial index of neutralization. The final additions should be of chalk-milk,—powdered chalk stirred in water to a milk, and used after the coarser parts have settled. Slaked lime is inadmissible, because it destroys the starch-sugar.

Neutralization being complete, the muddy contents of the boiling-tub are run into a wooden depositing-tank, of greater height than width, supplied with spigots for drawing off the liquid. In large establishments, a reservoir is placed in the ground adjacent to the boiling apparatus, and lined with brickwork. Into this, the contents of the boiling apparatus are drawn, and afterwards pumped into the depositing-vat. After the lapse of 12–24 hours, the sulphate of lime is deposited, so that the saccharine liquid may be drawn off. The sediment still contains a considerable amount of saccharine liquor. For the recovery of this residue, various methods have been applied, such as the following.

Filtering-barrels consist of vertically placed barrels with sieve-bottoms. Above the sieve-bottom, a piece of coarse cloth is spread, covered with cut straw or coarse river-sand, for the reception of the residue. The liquid runs out by the stopcock in the lower bottom, pure and clear. The first portion is returned to the filter. Upon the residue, gypsum-water is carefully poured, after the upper layer has been made even, and is somewhat loosened; the absorbed sugar-liquor is thereby dislodged. Or the residue is strained through bags or cloths, the press-cakes being again saturated with water, and the pressing repeated. The most general practice is to use bag-filters (described on p. 1889), or filter-presses (described on pp. 1838–9, 1848–9).

Evaporation and Refining.—The evaporation of the clear sugar-liquor is accomplished either over a direct fire or by steam. In the first case, flat pans are used, whose bottoms are only touched by the fire; in the other case, vacuum-pans. The evaporating cannot, however, be conducted uninterruptedly, since the solution yet contains dissolved gypsum, which begins to separate during the evaporation, by letting the liquid stand. The evaporating, therefore, is divided into two periods: (1) to a thin syrupy consistency, and (2) to a dense syrup after the removal of the gypsum. It does no harm to add sugar-liquor to the pan in the same ratio as the contents diminish by evaporation. The scum produced during the process is taken off with a skimmer.

As soon as the separation of gypsum makes it necessary, or when the liquor has reached a concentration of 20°–30° B., it is transferred into upright barrels, provided with spigots, for depositing and separating the gypsum. When finer cloths are put into a filter-press, the latter may also be used with advantage for separating the gypsum. When this is accomplished, after the lapse of several days, or at once if filter-presses have been used, the clear liquor is drawn off and evaporated in the same pans, or in extra pans, to a dense syrupy consistency (40°–45° B.). In large factories, vacuum-pans are used for this purpose. The deposits of gypsum from the barrels are placed in bag-filters, and then pressed.

Evaporation in open pans does not allow of economy of the steam or fuel; besides this, the liquor, when exposed to too high a temperature, acquires a dark colour, and, at the finish of the boiling, a strong formation of scum will ensue. Hence closed evaporating apparatus has for some time been used. Steam- and vacuum-pans have been already described (see pp. 1891–8).

As a brown colour is desired for glucose-syrup, if it is intended to be substituted for or mixed with cane-sugar syrups for making stout or porter, decolorization by means of bone-black (animal charcoal) is not always demanded. If the syrup is not to be decolorized, it is boiled down in the vacuum-pan to 40°–42° B. at 60°–65° (140°–149° F.), and again forced through the filter-press. The syrup, while passing through the filter-press, must be kept at a temperature of 75° (167° F.). The saccharine liquor is passed through filters of coarsely powdered animal charcoal (as is done in beet- and cane-sugar manufactories), or refined with fine charcoal, to produce an absolutely decolorized syrup, and to improve its flavour. The filtering through bone-black is best accomplished at 32° B. at 60°–65° (140°–149° F.). This is done after the gypsum has deposited itself by prolonged rest, the liquor being previously re-heated. If starch-syrup is long kept at a temperature near its boiling-point, it assumes a darker colour and becomes sweeter.

On the manufacture of solid starch-sugar, little needs to be added to the preceding remarks. Whether the syrup remains liquid, or in time congeals into solid, grainy sugar, depends less on its concentration than on its quality. If a quantity of dextrine is still present, the syrup will remain liquid even at 45° B. If the starch has been very completely transformed into sugar, the resulting syrup will, by good concentration, gradually congeal entirely to a grainy sugar. Such syrup is permitted to stand in moderately warm rooms, in wooden or earthen vessels, until it congeals. For producing a solid white sugar, the treatment with bone-black for the purpose of decolorizing is indispensable.

Liquid syrup is generally packed in strong casks or tuns of soft wood, and is liable to excessive shrinkage. During hot weather, its transportation is difficult, since the syrup often absorbs the water contained in the wood, the casks become dry, and the syrup leaks out. In case the boiling process has not been properly attended to, the product will easily ferment and spoil. Hence the article appears in commerce principally in a solid form. If the concentrated syrup, after cooling off, is stirred or beaten, it will coagulate in 8–10 hours so perfectly as to assume a soap-like consistency, without altering its quality. In this condition, it can be far better preserved and more easily transported. But liquid glucose which coagulates very quickly is not adapted to form an article of the syrup trade.

When the product is to be disposed of as solid sugar, and not as syrup, the liquor is evaporated in flat vessels to 40°–42° B., and then placed in crystallizing-pans. After the crystallization has commenced, the sticky liquid is filled into small barrels, where the mass in a short time entirely coagulates, and can be shipped. It may also be allowed to become solid in the pans, and then be ground and packed. Some manufacturers produce a dry and grainy sugar; it is then of importance that the transformation of the starch into sugar is as complete as possible, since the presence of great quantities of remaining dextrine will hinder granulation.

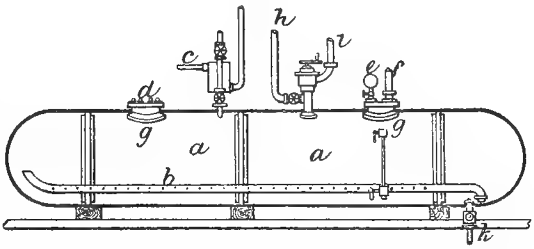
Common starch-sugar is identical with liquid starch-syrup, except in the proportions of water present; but in general, the composition is so varied that scarcely two samples are exactly alike, as may be seen from the subjoined analyses:—

	Starch-syrup.		Common Starch-sugar.		
	I.	II.	III.	IV.	V.
Water	21·8	20·8	27·8	27·4	26·0
Sugar	42·2	56·0	56·2	58·8	61·5
Dextrine and intermediate products	35·4	22·6	15·6	13·3	12·0
Mineral ingredients	0·6	0·6	0·4	0·5	0·5
	100·0	100·0	100·0	100·0	100·0

Other Methods.—There are a few other processes which have received application on an industrial scale. They are briefly as follows:—

Manbré's Method.—The conversion of starch into sugar proceeds much faster when the boiling takes place under pressure: upon this fact rests Manbré's method. The mixture of starch with diluted sulphuric acid is boiled at a high pressure, and at a temperature of 160° (320° F.). By this treatment, the action of the acid is increased, the transformation is more perfect, and the volatile oils which impart a disagreeable flavour are distilled off and destroyed. Use is made of a steam-boiler, constructed to withstand a pressure of 99 lb. a sq. in. (6 atmos.); it is lined inside with lead, and covered outside with a double casing. The intermediate space between the boiler and the casing is about 4 in. wide, and filled with non-conducting material. In the boiler *a* (Fig. 1398), is placed a perforated leaden steam-pipe *b*. The starch-milk is admitted by the pipe *c*, furnished with a stopcock; the boiler is supplied with safety-valves *d*, test-cock *e*, thermometer *f*, manholes *g*, receiving-pipe *h* for the products of distillation (volatile empyreumatic oils), steam-pipe *i*, liquor-gauge *k*, steam-pipe *l*, outlet-cock *m*, and water-pipe *n*.

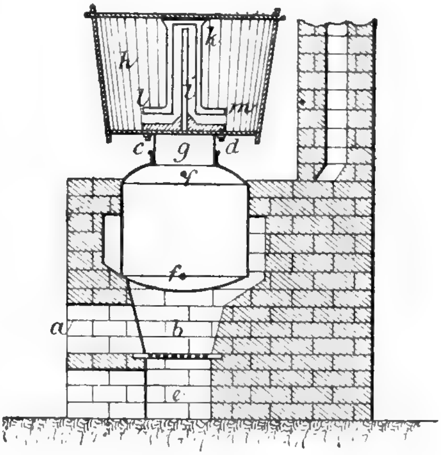
1398.



The substances are prepared for the boiler as follows:—61½ lb. of sulphuric acid at 60° B. are diluted in 6150 lb. of water. While this mixture is heated in the boiler to 100° (212° F.), a further 61½ lb. of sulphuric acid is diluted in 6150 lb. of water in an open wooden tank, supplied with a stirring apparatus. This mixture is heated by steam to 30° (86° F.). Into this latter liquid, 2464 lb. of starch are well stirred, and heated to 38° (100·4° F.). The starch-milk thus obtained is gradually poured into the boiling diluted sulphuric acid of the boiler by the pipe *c*, and the mixture is kept at a boil. As soon as all the starch is in the boiler, the cock of the conduit-pipe is closed, and steam is admitted until a temperature of 160° (320° F.) and a pressure of 6 atmos. are attained. The cocks *h i* are then opened for the outlet of steam and the products of distillation, while the temperature of the liquid is maintained by steam in the pipe *b* at 160° (320° F.), until samples taken out by the cock *k* indicate complete transformation. This is attained, according to the purity of the starch, in 2–4 hours. After ceasing to form sugar, the sweet liquor is to be drawn off, for the neutralization of the sulphuric acid, into an open wooden vessel, supplied with a stirring apparatus and waste-cock, and 185 lb. of purified carbonate of lime are stirred into 550 lb. of water, and gradually added to the liquor. The sulphate of lime thus formed is allowed to deposit, which occupies 2 4 hours. The neutral saccharine solution is filtered, evaporated, cleared, and crystallized as usual. The product is entirely pure, and free from any bitter or empyreumatic flavour.

Rössling and Reichardt's Process.—Rössling and Reichardt's apparatus for the manufacture of starch-sugar on a small scale is shown in Fig. 1399. *a* is the furnace-opening; *b*, the fireplace; *c d*, the mechanism for supporting the barrel, consisting of a ring-plate and pipe; *e*, the ashpit; *f*, apertures with pipes and cocks; *g*, the neck of the boiler; *h*, the barrel of white pine, with a bottom at least 1 in. thick; *i*, a tube made of linden or maple, 2 in. thick and ¾ in. wide; *k*, a pipe with four steam-outlets below, two of which are visible at *l m*.

1399.



Anthon's Method.—Excellent sugar is furnished by the method invented by E. F. Anthon, and patented in many countries. The manipulation is as follows:—2640 lb. of dry starch are stirred up in 373 gal. of water to a homogeneous milk, and run uniformly into the converter, previously charged with 53 gal. of water and 48 lb. of oil of vitriol, and brought to the boiling-point, so that the mass boils uninterruptedly. During winter, the starch may be stirred with tepid water, but not so warm that it becomes pasty. When the mixture has been kept at a boil for about 1 hour after the entire mass has been emptied in, the boiling is continued for 4–5 hours longer for making hard crystallized sugar, but when syrup is intended, 3 hours' boiling suffices.

For the neutralization, 66 lb. of good bone-black and 55–66 lb. of purified chalk are used. The chalk must previously be mixed in water and strained through a fine sieve. At first, 22 lb. of bone-black are gradually thrown in, and then the chalk-milk is poured in through a leaden pipe reaching down to the lower half of the boiling-vat. But great care must be taken that the seething liquid does not flow over. When the mixture reacts but moderately acid, the adding of chalk is interrupted, and the balance of 44 lb. of bone-black is added. It is a rule that ⅓ of the bone-black should be added before the chalk, and ⅔ afterwards. The finished mixture is boiled gently for about 10 minutes, and passed through a Taylor-filter.

For common coagulated sugar, the syrup is condensed to 33°–36° B. (hot); for hard sugar, to about 33° B. (hot). The syrup is passed through a small Taylor-filter, cooled, and a few lb. of half-congealed sugar of a former boiling are added and thoroughly stirred in. After 10–30 hours, the mass will become so stiff that for common sugar it can be put into barrels and left to harden. For hard sugar, the evaporation is stopped at 33° B., the stirring is not so strong, and is not so often repeated when the partly-coagulated sugar is being added. When the body of the sugar has attained a completely stiff consistency, so that it can only be scooped out with difficulty, it is subjected to pressure in a filter-press or centrifugal machine (see p. 1900).

To make "loaves," the press-cakes or sugar taken from the centrifugal are broken up into small pieces and melted, without adding water. This is done in a kettle over a steam-bath, aided by occasional gentle stirring, in a temperature as low as possible, continued until all lumps have crumbled, but not until the fine parts are dissolved. For 880 lb. of sugar, the operation occupies 3–4 hours. Complete solution of the sugar must be avoided, since those particles which float in the solution favour crystallization. When the mass has attained the proper consistency, it is cast into the moulds; in 2 days, it is entirely solid.

The press-syrup can either be mixed with such syrup as contains a large amount of dextrine, and sold as such, or boiled and worked over again so as to make a second product of press-cakes. To this end, it is evaporated to 36°–37° B. (hot), cooled off and coagulated as usual, and pressed out. The press-cakes thus obtained are inferior, and it is best to dispose of the press-syrups as such.

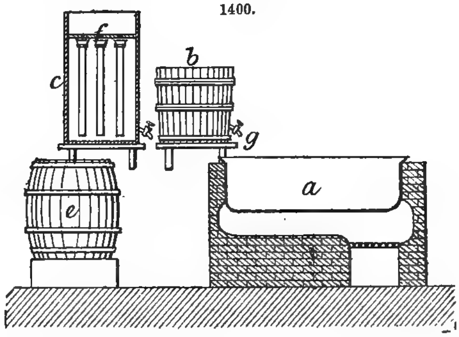
To obtain a product of the whitest possible colour, the application of sulphurous acid is resorted to. After half the chalk has been applied in the neutralization, 3–4 lb. of dry or 11 lb. of liquid sulphite of lime are added, continuing the boiling for 10 minutes, and then adding the rest of the chalk. It is imperative to carry out the process with great cleanliness, and to use no water which contains hygroscopic ingredients.

In Anthon's method for producing 3–4 cwt. of starch-sugar per 24 hours, the ingredients for a boiling are:—

370 lb. of air-dry starch.
11 „ of sulphuric acid of 66° B.
3·70 „ of bone-black.
2·46–3·70 lb. of pure lime.
4·95 lb. of prepared chalk.

The apparatus is very simple, and is represented in Fig. 1400: *a* is the pan; *b*, a vat of about 8½ bush. capacity, with a wooden spigot *g* at the bottom; *c*, a Taylor-filter in a case 4 ft. high and 2 ft. wide and deep, arranged for the reception of 9 bags, each about 2½ ft. in length, and 6–7 in. diam. when filled, and set up so that the thin liquor can be drawn off by a small gutter into *e*. The bags are made of grey linen of prime quality and uniform weft, and are fastened over the funnels *f* with strong cord.

1400.



Capillair-syrup and -sugar.—Some few establishments have furnished quite recently a water-clear syrup, which, in a very condensed state, is known in the market as "capillair-syrup," and is extensively used by confectioners and others in the United States. The mode of producing it is as follows:—After the usual boiling and neutralization, the clear, thin liquor of 16°–20° B. is concentrated in a vacuum-pan to 30° B. (boiling hot). The vacuum-pan is of copper, because by this process the gypsum deposits itself on the copper pipes as firmly as stone, and the pipes have to be frequently cleaned by the aid of hydrochloric acid.

If the temperature can be maintained at 57½°–63¾° (145½°–146¾° F.), the syrup will remain of a lighter colour, as also with rapid evaporation. Since the gypsum never completely separates from this heavy syrup, filter-presses are used. Thus the clarifying is much accelerated, and the thin syrup issues from the filter-presses free from gypsum, and entirely clear. It is directly pumped into the reservoir, thence to the bone-black filter, and is then drawn into the vacuum-pan, and evaporated at 56½°–62½° (133¾°–144½° F.). If the syrup is for exportation, the concentration is carried to 44° B. at 61° (142° F.). The evaporation goes on very quickly, since the syrup already possesses a consistency of 28°–30° B. It has to be filled into the casks while yet lukewarm. If it cools off entirely, it will not run out of the vats at all.

The perfectly white and finest quality of starch-sugar, which also passes through the bone-black filters, is known as "capillair grape-sugar," and is manipulated in a similar way, with this difference, that the syrup at the last stage is condensed to 44°–45° B., while for the production of sugar, the process of evaporating must be stopped as soon as the syrup has reached the consistency of 40°–41° B. This sugar has been mostly packed in cases of 1 cwt.; but more recently it is cast into blocks and loaves, which are afterwards grated, and the sugar packed in bags. This method of packing in bags is more practical and advantageous than in boxes, since the sugar adheres to the wood of the boxes, and much of it is lost.

Granulated Starch-sugar.—The manufacture of granulated starch-sugar was introduced by Fouchard, at Neuilly, France. The transformation of the starch into sugar is accomplished in the ordinary manner, but at an increased temperature and pressure, as a great amount of dextrine would hinder the granulation of the sugar.

The liquor, saturated with lime, is run through a bone-black filter, to impart to it the colour of a nice clear "covering" sugar. The filtered liquor is evaporated in summer to 30° B., in winter to 28° B. (boiling), and run into capacious clearing-tanks, where the greater part of the gypsum settles; the tanks are in a cool place, or the cooling is accelerated by the use of worms in which cold water circulates, so as to avoid fermentation. After the lapse of 24–30 hours, the syrup is cool and clear, and is then placed in vertical barrels, left open above, and whose bottoms are perforated with small holes, thus forming a sieve-bottom. During the process of crystallization, these openings are kept closed with small wooden pegs or taps. The barrels stand on a framework over a lead-lined gutter. In 10–12 days, crystallization begins by the formation of small accumulations in the syrup, which gradually increase. As soon as the syrup is about ⅔ filled with crystals, the holes in the bottom of the barrels are opened, draining off the molasses, while the soft crystalline accumulations remain in the barrels.

As soon as the draining appears to be finished, this is perfected by placing the barrels in an inclined position. The molasses thus obtained is again boiled in sulphuric-acid water, to transform the dextrine present into sugar. The granulated sugar is then placed on gypsum slabs to the thickness of 4 in., and dried at 22°–25° (71½°–77° F.). By increasing the temperature, the crystals would melt and stick together. This lump formation cannot be entirely avoided. If the lower part of the layer begins to get dry and white, it is turned. In 3–4 days, the sugar becomes perfectly dry, and is then, for the purpose of an even separation, rubbed through a sieve, and the lumps which do not pass are ground between a pair of porcupine-rollers. Usually the sugar is again spread on gypsum slabs.

Uses of Starch-sugar and Glucoses.—These products are used chiefly for brewing, for the manufacture of table-syrups and candies, as food for bees, and for making artificial honey. All soft candies and taffies, and a large proportion of stick candies and caramels, are made of glucose-syrup. Very often a little cane-sugar is mixed, in order to give a sweeter taste to the candies, but the amount of this is made as small as possible. A very large percentage of all the starch-sugar made is used for the manufacture of table-syrups. Some kind of cane-sugar syrup is added until the tint reaches a certain standard. The amount of cane-sugar syrup required varies from 3 to 10 per cent., according to circumstances. These syrups are graded A, B, C, &c., the tint growing deeper with each succeeding letter. Small quantities of glucose-syrup are used by vinegar-makers, tobacconists, wine-makers, distillers, mucilage-makers, and perhaps for some other purposes.

The solid sugar is also used for many of the purposes enumerated, but chiefly for the adulteration of other sugars. When it is reduced to fine powder, it can be mixed with cane-sugar in any proportions, without altering its appearance. Since starch-sugar costs less than half the price of cane-sugar, this adulteration proves immensely profitable.

The cost of manufacture is about ½*d.* a lb. Some 26–32 lb. are made from a bushel of corn. It is sold by manufacturers at 1½*d.*–2*d.* a lb.

Sugar-refining (*Raffinage du Sucre*; Ger., *Zuckersiederei*).—Very large quantities of sugar are consumed in their "raw" state, just as they reach the home markets from the plantations; but others are so impure as to be unfit for immediate use. The purification of these latter, and the preparation of fine sugars from the low grades, is the work of the refiner. The estimation of the impurities, and the qualities of the various kinds of sugar, will be found detailed under the section on Analysis. The appended analyses, however, present a comparison of the relative mineral impurities in cane- and beet-sugars as regards bases, the phosphoric and carbonic anhydrides and the chlorine having been displaced by the sulphuric acid employed in the analysis, and the results being calculated on the ash. It will be noticed that cane-sugar ash contains larger proportions of lime, magnesia, ferric oxide, and sand, than beet-sugar; while potash and soda largely predominate in the latter:—

	Cane-sugar Ash.	Beet-sugar Ash.
Potash	28·79	34·19
Soda	0·87	11·12
Lime	8·83	3·60
Magnesia	2·73	0·16
Ferric oxide and alumina	6·90	0·28
Sulphuric anhydride	43·65	48·85
Sand and silica	8·29	1·78
	100·06	99·98

In addition to these, there are glucose, low sugars, and organic matters of other kinds, which it is desirable to remove.

Synopsis of Operations.—No two refiners follow precisely the same process in all details; and as it would cause much confusion to introduce the deviations as they occur, the preferable plan will be to commence with a general account, and to supplement this with particulars of special methods.

In planning a refinery, it is very desirable, in fact almost absolutely necessary, to arrange the various plant and machinery so as to allow the liquor so far as possible to descend by gravitation during the different processes, and so avoid pumping. For this reason, refineries are built in blocks seven or eight stories high, and all the raw sugars to be refined are hoisted by crane to the top of the house, the refined article being discharged at the bottom.

The refinery must have an ample supply of good water, for melting the sugar, washing bags, working vacuum-pans, washing char, &c.; cleanliness in a refinery is a matter of first importance, and a limited supply of water is one of the greatest drawbacks which a refiner can be subjected to, as it not only prevents him from recovering the whole of his sugar, but, if the water is bad, renders him liable to a multitude of complications, the causes of which he is at a loss to account for.

The first operation after the raw sugar has been hoisted to the top story of the house, is to break open the bags or hhds. In the case of hhds., the sugar is tipped directly on to the floor, the hhds. are scraped, passed into a steam chamber, steamed, and washed with hot water, so as to remove the whole of the sugar. The contents of the bags are tipped directly on to the mixing-floor, or into the dissolving-pans, and the bags are steamed and washed. The steaming and washing of bags is of some importance, as bags containing 80–100 lb. of sugar will frequently retain 1–2 lb. of raw sugar, which is only recovered by steaming and washing; the water used in washing should not be too hot, neither should the bags be steeped for too long a time, more especially in the case of mat or grass bags from China and the East, as they frequently contain notable quantities of alkaline salts and colouring matters, which are readily dissolved by treatment with boiling water, rendering the refiner's work more difficult, and lessening the quantity of refined sugar produced. The sweet waters from bag- and cask-washing are run into the blow-up pan before they have time to ferment.

The blow-up is set immediately below the mixing-floor, and is a cast- or wrought-iron tank, provided with a vertical shaft and mixer, as well as one or two copper coils through which live steam can be introduced. It is capable of holding 7–10 tons of sugar, which when melted to 28°–30° B. will measure 3000–4500 gal.; the steam coils are covered either with sweet water from bag-washing, or fresh water. Steam is turned on, and the raw sugar is either shovelled in from the mixing-floor above, or delivered direct from the bags. In working, it is customary to run in water up to a certain mark on the blow-up; the water of condensation produced by the live steam adds further to this quantity, and probably fills the blow-up something less than half full. Mixed or analyzed sugar is then filled in gradually until the blow-up is full to within 4–6 in. of the top, steam blowing in during the whole time. When the sugar is thoroughly melted, the sp. gr. is taken with a Baumé hydrometer, and should be 25°–27° B., which will equal 27°–30° when cold. The quantity of sugar melted at one time varies from 5 to 8 tons; it of course greatly depends upon the quality of the raw sugar used; a much larger quantity of low-class sugar is required to fill the blow-up than is necessary when good crystallized sugars are used. The time occupied in melting this quantity of sugar is about ½ hour, and it is necessary in the case of very low sugars to partially neutralize the acidity with a few buckets of lime-water thrown into the blow-up during the operation of melting. This causes a precipitation of some of the soluble organic impurities, which are thrown down in brown flocks, and removed in the subsequent stages of the process. It is also necessary during this operation to remove by skimming the pieces of wood, cane, grass bags, and other miscellaneous articles which are present in low sugar, and which rise to the surface along with a dirty scum. The liquor thus prepared is run first through a wire strainer which removes hairs, sacking, and fibres, and any pieces of matting which may have escaped the operation of skimming.

The liquor runs from this strainer (or in some cases the valve at the bottom of the blow-up delivers the liquor directly into the bag-filters, without passing through the wire strainer) into the bag-filter box.

Bag-filters.—Those generally in use are Taylor's, and have already been described on p. 1889. Refineries are always provided with a large number of boxes, each box holding 400–500 bags, and placed immediately below the blow-up pans. The filtration through these is a tedious operation, on account of the exceedingly slimy nature of the insoluble organic matter, which though small in amount, is of such an objectionable character as to coat the inside of the bags with a tenacious deposit not more than $\frac{1}{16}$–$\frac{1}{8}$ in. thick, which prevents the liquor finding its way through; for this reason, the quantity of liquor filtered through a box of 400 bags is not much more than 2000–3000 gal., or say about 5 tons of sugar per day. Of course this amount depends greatly upon the quality of the raw sugar, and the amount and nature of the insoluble organic matter which it contains. Previous to starting the filter, it is necessary to steam out the box containing the bags, so as not to cool the first portion of the liquor running through. After the filter has finished working, the upper part is filled up with boiling water, and allowed to stand some hours, until the whole of the water has filtered through the bags, removing with it the greater part of the sugar; the bags are then steamed, rewashed if necessary, taken from the box, and dried ready for further operations.

The liquor as it runs from the bag-filters is dark in colour, but clear and bright, and it now remains to remove from it the whole of the colouring matter and soluble organic impurities, which is done by means of filtration through animal charcoal. The action of the charcoal in removing the colouring matter is not clearly understood. It is sufficient to say that almost any sugar, no matter how dark in colour, can be rendered as clear as water by using sufficient bone-black in a finely divided condition, taking care that the liquor when filtered is as nearly boiling as possible. The liquor from the Taylor's filter is received or pumped into tanks placed above the charcoal cisterns, provided with steam-coils in order to heat up the liquor previous to passing into the char.

Charcoal cisterns.—These are now made of cast-iron, and in large refineries are capable of holding 30–40 tons of char; they are enclosed at the top, the charcoal being packed tightly, and the liquor being forced through under 3–7 lb. pressure (see pp. 1851–3). The cisterns are packed tightly with well-burnt dry char, and the hot liquor is run in at the top, the cock at the bottom of the cistern being open so as to allow the confined air to escape. When the cistern is full of liquor, it is allowed to stand for 3–4 hours "to settle." At the expiration of this time, the cock drawing from the bottom, on the upright pipe which leads the fine liquor above the surface of the char on the outside of the cistern, is opened, and the stream of liquor, which is perfectly clear, is adjusted so that the decolorizing power of the char is not too rapidly spent; or in other words, the liquor must be left a sufficient time in contact with the char to allow the latter to act upon the organic impurities. As a rule, all the discharge-pipes from the cisterns are brought into one room, and arranged over a number of gutters communicating with an equal number of tanks to receive the fine liquor. At first, no colour can be detected in the liquor, but after a while, the time depending upon the purity of the sugar operated upon, and the quality of the char, the liquor begins to assume a yellowish tinge. Previous to this, however, the attendant has altered the course of the liquor, and it is now flowing into another tank, the first portion being used for making the finest refined article, either loaves or crystals; the second portion, received in a separate tank, is used for making crystal-sugars, which have not a similar degree of whiteness and brilliancy. The cistern is worked until the decolorizing power of the char is exhausted, or until the liquor running away is only slightly superior in colour to the liquor as delivered into the cistern. Occasionally the liquors having a slight tinge of colour are reheated and used to "settle" a fresh cistern of revivified char, following with the liquor from the bag-filters; by this means, a larger quantity of liquor of 1st quality is obtained at a comparatively small cost, as the amount of colouring matter which these liquors possess is not sufficient to materially reduce the decolorizing power of the animal charcoal.

As a rule, charcoal cisterns are always "settled" or started with fairly good liquor, which is followed by raw sugar liquors, or syrups. If the charcoal is not thoroughly exhausted after the syrup, molasses (or more correctly syrup from last boiling) is run through the cistern.

It is necessary so soon as the charcoal is exhausted to wash it free from sugar. Boiling water is run on to the char, which carries before it in its downward passage the sugar liquor. The washings of the char are run into the syrup-tanks so long as they stand at or above 18° B.; below this the liquid gradually getting weaker and weaker is run into a separate tank, the washing being continued until the liquor marks 1°–2° B. At this stage, the bottom cock on the cistern is opened, and sufficient boiling water is run through the char to thoroughly wash it free from traces of sugar and organic impurities; the cistern is then emptied, and the char is dried and revivified. The weak waters used for washing, and marking 7°–15° B., can be used for washing off another cistern, or in the blow-up for melting a fresh quantity of raw sugar. It is important that they should be used quickly, as otherwise they are very liable to undergo fermentation. The quantity of charcoal used depends entirely upon the quality of the raw sugar passing through; in general, ¾–1¼ tons are required per ton of sugar, and, with low Manilas, even more than this. Charcoal attains its greatest power of decolorizing syrups after being 4–6 months in use; each revivification seems to greatly increase its absorptive powers, until a certain point is reached, after which it gradually deteriorates, and requires mixing with a proportion of new charcoal in order to keep up its action.

Revivification of the Charcoal.—(Several forms of revivifying-kiln have been described under Beet-sugar, pp. 1853–4.)

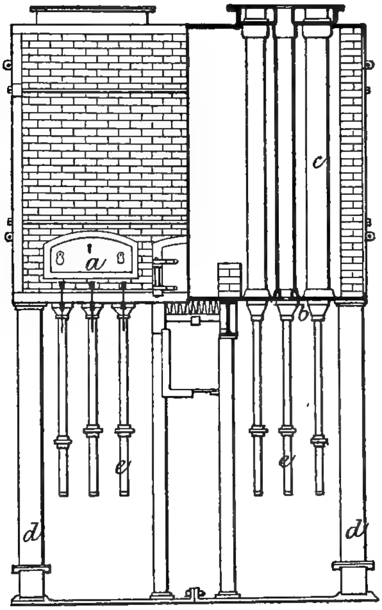
The practice of washing the char, after its removal from the cylinders, with hydrochloric acid, with the object of taking out salts of lime absorbed from low sugars, appears to be rarely adopted in this country. But when the washing with hot water is performed too slowly, the weak saccharine solution which results is apt to acetify, and this produces a similar result, which is recognized by the solution being opaque and milky when it is run off. This acetification is more likely to occur when the char has been in use for too long a time, and more readily in old than in new char. New char will often give off liquors smelling of sulphuretted hydrogen when the sugar refined is acid. Acetification will also occur under conditions which are little understood, but over which refiners have no power of control. Also when imperfectly washed char, which after draining may still retain sweet water, is allowed to stand for some indefinite time before being reburned, it is apt to ferment and acetify. This fermentation is sometimes regarded as a benefit to the char, serving to open it by removing matters within its pores which mere washing will not get rid of.

The principal forms of kiln used in this country are as follows:—

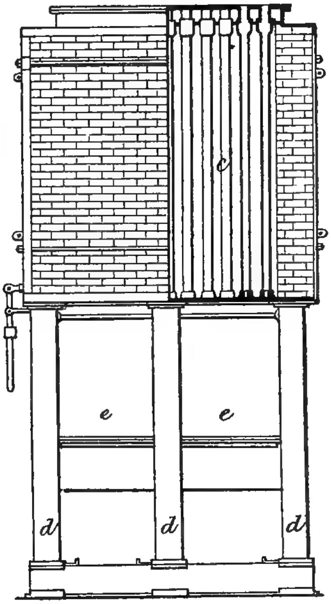
The pipe or tubular kiln, made by McLean and Angus, Greenock, is illustrated in Figs. 1401–3. Each reburner consists of a series of 64 iron pipes *c*, arranged in two banks or groups of 32 each on either side of a central fire, the whole being raised upon iron columns *d*, which, being hollow, are made to serve as flues. The flame from the fire plays among these pipes, and is regulated by appropriate dampers. In the brickwork enclosing the pipes, opposite each group, is an iron plate *a*, with an arrangement for viewing the several rows of pipes. Beneath each of the six rows into which the pipes are distributed, is a narrow iron box *e*, freely exposed to the air, and serving as a cooler for the reburned char. A slide-valve at *b* permits the discharge into the cooler of the lower portion of the contents of the pipes from time to time, the coolers being emptied below upon the floor, or into vessels run in under them. The top of the kiln where the open ends of the pipes appear forms a platform near the roof of the building where the apparatus stands. Upon this platform, the damp char is heaped up, and there undergoes some preliminary drying by evaporation. Whenever a cooler is refilled, the char sinks commensurately in the pipes corresponding to it, and a workman upon the platform at once with the shovel refills the pipes to the top. Whatever vapours are evolved by the reburning escape from the top of the char-pipes, and pass out of the building through openings in the roof.

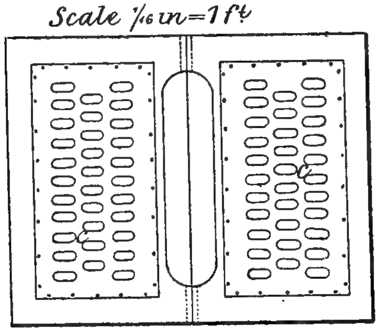
The Buchanan & Vickess reburner is a modification of the preceding, which, while it is said to burn the char more equably, provides for the collection of the vapours that are given off. Fig. 1404 shows those parts of the apparatus which it is necessary to describe. The tubes *a* are arranged much in the same way as in the ordinary reburner. Each pipe, however, is double, consisting of a wide external tube *b*, and a narrower internal tube *c*, and the char, falling from a platform above, occupies the space *d* between the two tubes. The internal tube is provided with openings *f* in its circumference at definite intervals, and these openings are protected from the ingress of char by a louvre-like projecting plate, inclined downwards at an angle, from the part of the tube immediately above them. The vapours given off during the reburning pass through these openings into the interior of the tube *c*, which opens above, together with other tubes in the same row, into a horizontal channel or flue *g*, which conducts the vapours away. The outer tube is made to revolve in its longitudinal axis around the inner one. There are also revolving coolers *h* below.

1401.



1402.

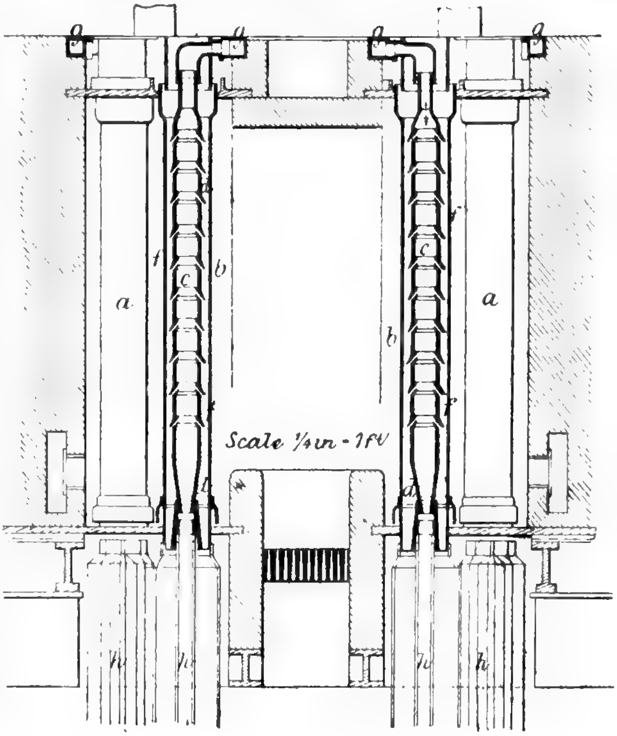




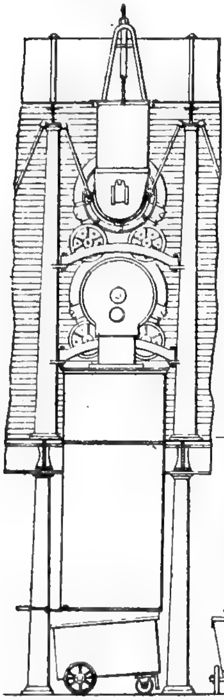
1403.

Of revolving cylinders, perhaps the best is Brinjes', shown in Figs. 1405–8. Fig. 1405 represents a front elevation of the apparatus complete; Fig. 1406, a sectional elevation; Fig. 1407, a back elevation; and Fig. 1408, a sectional plan. In a brick setting, are two horizontal retorts, each of which receives a circular reciprocating or alternating motion of nearly one entire revolution on its longitudinal axis. The upper retort acts as a drying-chamber for preparing the charcoal for the revivification which takes place in the lower retort; and it is contained in a separate brick chamber of its own, which is situated immediately above the roof of the furnace, the heat from which, after circulating round the lower retort, enters the upper chamber through openings left for that purpose in the roof of the furnace, and then acts upon the upper retort before passing off to the chimney. The two retorts are provided with a series of internal flanges at intervals of about 6–8 in., and ledges are formed between the flanges for carrying up the charcoal as the retorts reciprocate. An opening is made through each flange, and all these openings are disposed in a line with each other. To cause the charcoal to travel continuously along the retorts during the process of revivifying, an angled projection, somewhat after the form of a 3-sided pyramid, is cast inside the cylinder in each of the intervals or spaces between the several internal rings or flanges, and exactly in the centre line of the openings in these flanges. The two opposite sides of these projections present reverse angles, both of which direct the charcoal into the next space on the partial rotation of the retort. The upper retort is driven direct by a mangle-wheel and pinion arrangement; and this motion is transmitted to the lower retort by means of an endless chain, suspended from the rear end of the upper retort, and passing under the corresponding end of the lower

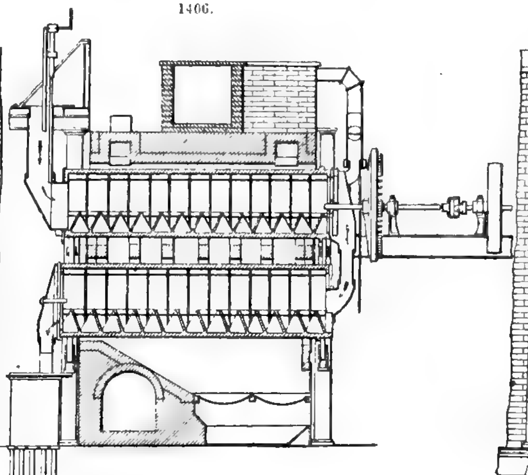
1404.



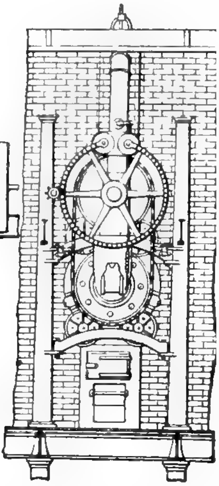
1405.

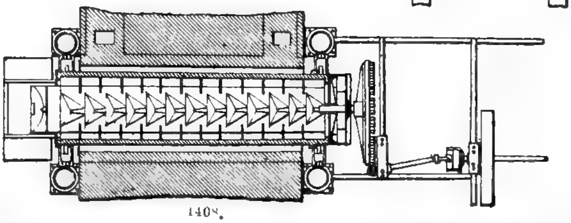


1406.



1407.





1408.

retort. Both ends of the retorts are supported upon anti-friction pulleys, carried in the transverse framing, bolted to the main supporting column. The feeding hopper opens to a flue, from which the charcoal is shovelled when being supplied to the retorts, the feed being nicely adjusted by means of the sliding-door, worked by a winch-handle and screw-spindle. A sliding door, covering an opening in the inclined side of the hopper, is for the purpose of inspecting the interior of the retort; a spy-hole is also provided in the stationary front cover of the lower retort. The upper retort discharges its contents into a conduit, which conducts it to the lower retort, after traversing which, it is discharged down a pipe into an enclosed receiver. From this receiver, it passes through the cooler, which consists of a number of long narrow passages, placed side by side, and having intervening air-spaces between them for the more effectual cooling. By the time the charcoal has traversed these coolers, it is sufficiently cool to be exposed to the action of the atmosphere, and is discharged into a small truck. The vapours which are evolved during the reburning are carried off by a pipe, provided with a throttle-valve, communicating with the chimney. The entire arrangement is supported upon strong iron girders, resting upon columns in the basement.

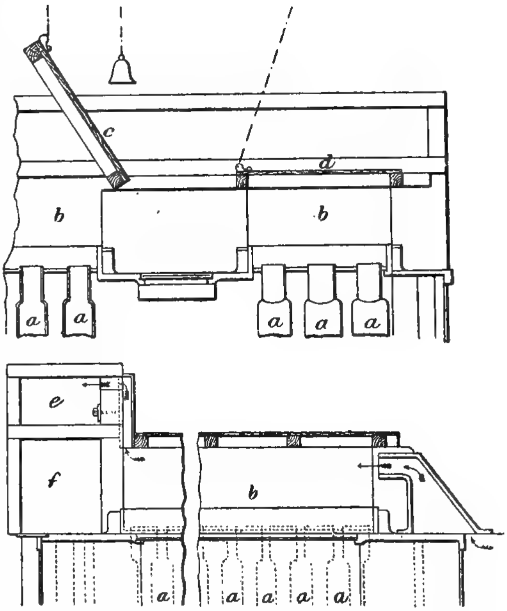
When the revivified char is cold, it is sifted, and the dust is sent away to the manure-makers, as is also the finally spent char from the filters (see p. 1266).

Under the most favourable circumstances, the vapour that issues from char in process of revivifying has usually a sweetish and slightly empyreumatic odour, but is never overpowering, though sometimes sufficiently pronounced to be very disagreeable. Whatever ill odours may attach to the vapours must depend upon the evolution of sulphuretted hydrogen, and the products of decomposition of the organic matters taken out of the raw sugar in its passage through the charcoal. The remedies obviously consist:—

1. In the thorough washing of the char before reburning, so as to remove from it as much as possible those matters which by their burning give rise to offensive effluvia. At James Duncan's refinery, pressure-cisterns are in use to hasten the passage of the syrup through the char, and the washings, similarly hastened, are continued for 6–7 hours after the last of the sweet water has been removed. The time that elapses from charging a charcoal cistern to the char again going to the reburner is not more than 35 hours. Fermentation is thus altogether prevented.

2. Means should be adopted for collecting and disposing inoffensively of the vapours proceeding from the reburning. When Brinjes' reburner is in use, the vapours are collected as a matter of course, being conducted first into a long brick chamber or flue 3 ft. sq. internally, and thence into a chimney-shaft at a point below that at which the furnace-flue enters; this shaft discharges them at a sufficient elevation to prevent any nuisance. At other works, the vapours are discharged at once into a tall chimney-shaft, without occasioning nuisance. Should it be thought necessary, means of condensation might readily be added to this apparatus. There may be some difficulty in collecting the vapours proceeding from pipe-kilns, but it is nevertheless practicable. At Duncan's works, a space *b* above each stack of pipe-kilns *a* is boxed with a wooden cover *c d*; hot air is conducted into this space from the fire by means of an appropriate flue *e f* at one end, and passes out at the other end, carrying the vapours with it into a chimney. This arrangement is shown in Fig. 1409. At one part of these works is a common horizontal flue to receive all the vapours from a row of reburners; and, should it be requisite, the vapours might very readily be condensed. After condensation of all that is condensable, the remainder might be passed through a fire. One of the advantages of Buchanan's reburner is that provision is made for the collection of the vapours.

1409.



Boiling.—The next operation is the boiling of the decolorized liquor; this is performed in vacuum-pans already described (pp. 1854–7), the method of boiling not essentially differing from that detailed on pp. 1893–5. In the case of crystal sugar, the grain is obtained low down in the pan, the crystals being fed by the admission of fresh liquor; care is taken not to drown the small crystals of sugar already formed, and not to boil so low as to cause fresh crystallization.

Several methods are employed in order to obtain a large grain, such as cutting the charge, i. e. when the pan is quite full, half the sugar is run out, and fresh liquor let in upon the remaining half in the pan, and the pan is boiled full; the crystals in this case are considerably increased in size, as the fresh liquor deposits its sugar on the surface of the crystals remaining in the pan. It is important in boiling for grain to feed the grain often, and with a comparatively small amount of liquor each time; to boil at as low a temperature as possible, with a good vacuum of 26–27½ in.; and to take a proof at least every few minutes, especially when grain is expected and when the crystals are "growing." The proof is carefully examined on a sheet of glass; when the boiling is nearly finished, the "proofs" are almost solid, and the liquid in which the crystals are suspended sets almost immediately on being spread about on the plate of glass. At this stage, it is sometimes customary to increase the temperature some 10°–15°, in order to harden the grain. The *masse-cuite* is quickly let out of the pan into a tank, which is sometimes circular and provided with a mixer and steam-jacket; this arrangement is called a "heater"; from the heater or tank, it is delivered by suitable mechanical appliances to the centrifugals. Numerous mechanical contrivances are in use for delivering the *masse-cuite* from the heater or tank to the centrifugals. Small iron trucks suspended or running on rails, passing under the heater and over the centrifugals, and making a complete circle, are frequently employed; the truck, which is of a convenient size to supply one or two centrifugals, is passed under the heater, the slide-valve is opened, and the truck is filled with *masse-cuite*; this is run over the first centrifugal, a slide-valve is opened at the bottom of the truck, and its contents are delivered into the centrifugal, which has previously been started and is running at a slow speed.

The "heater" is now dispensed with in most refineries, and its place is taken by some less complicated form of apparatus; it is certainly not necessary to provide it with a steam-jacket; the stirrers require powerful machinery to drive them, and it is questionable whether they really fulfil any useful purpose, provided the *masse-cuite* is centrifugalled within a few hours after its leaving the pan. First *masse-cuites* from fine liquor are generally boiled to a high degree of consistency; the amount of water which they contain varies within slight limits, but is generally between 7 and 10 per cent. The colour should be only very slightly yellowish. The yield of crystal sugar from highly-refined *masse-cuites* is from slightly under 50 to perhaps 55 per cent. of the weight of the *masse-cuite*; it rarely runs above the latter figure.

In the case of loaf or cube sugar, the liquor is boiled for small grain, and the *masse-cuite* is run out very stiff, containing not more than 7 per cent. of water. The *masse-cuite* is filled into moulds. In the case of loaf, the loaves are kept in a warm room for some hours, until the sugar is nearly set; the moulds containing the sugar are then elevated to the upper portion of the house, and the sugar is allowed to solidify and liquored with fine liquor at 25°–30° B.; when the requisite degree of whiteness is obtained, as much of the liquor as possible is drawn away by means of suction, and the sugar is dried in ovens, and turned out of the moulds, when it is ready for sale. With cubes, the *masse-cuite* is filled into peculiarly-shaped moulds which fit into a large centrifugal machine; after the sugar has set, the moulds are transferred to the centrifugal machine, washed or liquored in the machine, dried, and packed. The yield of refined sugar by this means is 70–80 per cent. of the weight of the *masse-cuite*; but the extra time and labour required in handling the loaf-sugar does not more than pay for the increased yield by this method, over the 50 per cent. obtained in the mode of making crystal sugar already described.

The Alum Process.—The "alum process" for removing potash, ammonia, and other impurities from saccharine solutions (see also pp. 330–2), is due to James Duncan, and John A. R. and Benjamin E. R. Newlands. Beet-syrups contain a notably large proportion of potash salts, which much retard crystallization. The salts in beet-molasses, according to Dr. Wallace, are:—Chloride of potassium, 18·70 per cent.; sulphate of potash, 4·18; carbonate of potash, 53·80; carbonate of soda, 20·81; carbonate of lime, 0·35; magnesia, 0·27; moisture and loss, 1·99. A sample of French beet-molasses gave 10·86 per cent. of ash, 4·88 being potash. Out of 3·40 per cent. of ash from English beet-syrup, 1·36 is represented by potash. Low-class cane-sugars also contain notable proportions of potash:—Dutch Bastards, 0·33; Guatemala, 0·40; Penang, 0·71; Low Penang, 0·57; Medium Penang, 0·23; Egyptian, 0·63, 0·53, 0·80; Jaggery, 0·49; Clayed Manilla, 0·23; Iloilo Manilla, 0·58 per cent.

The alum process consists of two parts: 1st, precipitation of the potash in the form of alum; 2nd, neutralization of the residual acid liquor by means of lime.

1. Precipitation.—This is accomplished by adding to the cold syrup a solution of sulphate of alumina, sufficient to form an alum with the whole of the potash present. It is convenient to work with syrup at about 38° B., and solution at 27° B.; if the syrup be much over 38° B., the alum cannot easily settle out. The mixture is well stirred for ½–1 hour, and the whole is allowed to

repose for 4–5 hours, until the deposit—which consists of small alum crystals, known as "alum meal"—has completely subsided. The "alum-tank" in which this operation is performed is provided with mechanical stirring-gear. The three principal requisites in order to obtain the best results, and to prevent the formation of uncrystallizable sugar, are:—(1) To work at the lowest temperature; (2) to employ solutions as dense as possible; (3) to perform the whole operation as quickly as is consistent with separation of the alum.

The amount of potash present in syrups is generally equal to $\frac{3}{5}$ of the ash, determined in the usual way (see p. 1946). Every 1 part of potash requires for conversion into alum about 9½ parts of sulphate of alumina, of which, 2½ parts are required to convert the potash into sulphate, and the remaining 7 to combine with the sulphate of potash, so as to form alum. If the liquor contains free or combined sulphuric acid, or if the solution of sulphate of alumina contains any free sulphuric acid, the 2½ parts of sulphate of alumina required to convert the potash into sulphate may be partly or entirely dispensed with. For practical purposes, it suffices to determine the percentage of ash, to assume $\frac{3}{5}$ of this to be potash, then to multiply the percentage of potash by 9·5, which gives the dry sulphate of alumina, and, lastly, to ascertain the amount of solution corrresponding to this.

2. Neutralization.—The alum-tank is provided with several taps, at different heights; when the alum has well settled down, the clear acid liquor is run off, by means of these taps, into a "liming-tank" placed on a lower level, and also provided with mechanical stirring-gear. As soon as the acid liquor has been thus decanted into the liming-tank, a little finely-divided chalk, previously made into a paste with water, is added, so as to produce a slight effervescence. Milk of lime is then added at frequent intervals, until the froth has nearly, but not entirely, disappeared: the gradual abatement of the froth indicates when the neutralization is nearly complete. This operation takes 1–2 hours. The point at which the neutralization is practically complete may be known by:—(1) The absence of any large amount of froth; (2) the absence of any taste of aluminous compounds; (3) the liquor should give only a *dull*-red tinge to blue litmus-paper. When the neutralization is thus practically complete, the treated liquor is subjected to the same routine as ordinary sugar-solutions in a refinery: it is heated in the blow-ups to 65° (150° F.), but not higher, then passed through filter-presses, and through char, and boiled down in the vacuum-pan.

To wash and dry the precipitated alum, it is convenient to employ a small centrifugal machine. After once "machining" for a few minutes, a little water being added as usual during the operation, the alum appears white and dry, but still retains a small amount of syrup. It is then mixed with some cold water, and machined a second time, after which it is free from sugar, and fit for sale.

The following analyses show the effect of the process on beet-syrup treated on a large scale:—

	Beet-Syrup.	After Treatment, and before Char.	After Treatment, and after Char.
Sugar..	60·18	40·54	41·60
Ash	3·61	1·33	0·47
Water, &c...	36·21	58·13	57·93
	100·00	100·00	100·00

The advantages of the process are:—(1) The removal of potash and ammonia from syrups without much dilution; (2) the removal of much colouring and albuminous matters; (3) considerable improvement in flavour and odour; (4) the alum produced is nearly equal in value to the sulphate of alumina used, so that the expense of the process is not great; (5) the plant required is of the simplest description, the cost of labour is small, and the operations are continuous and rapid.

The process has been in constant operation during several years at the sugar-refinery of James Duncan, Clyde Wharf, Victoria Dock, London, where the syrup from many thousands of tons of sugar have been treated with excellent results, several hundred tons of potash-alum of good quality being during the same time produced, and sold at a fair market-price. Licenses to work the process have been taken by nine of the principal refiners of the United Kingdom, and others have been granted to several refiners in Holland, Belgium, and the United States.

The foregoing description applies to the process as actually conducted at the Clyde Wharf Refinery; various alterations are advantageous under particular circumstances.

Strontium.—Strontium is a powerful base for extracting sugar in the refinery, as it combines with 3 equivalents of sugar. Native strontianite, containing 90–95 per cent. of pure carbonate of strontium, is said to be now largely employed in Continental sugar-refineries. This has hitherto been obtainable only with difficulty, but recently in Westphalia it has been worked to a great depth in mines, and a supply of many thousand tons per annum is said to have been secured.

Oxalic Acid.—C. H. Gill has proposed to effect the removal of potash from saccharine solutions by the addition of oxalic acid, in the state of powder, or of hot or cold solution, in quantity sufficient to form oxalate, binoxalate, or quadroxalate of potash, or a mixture of these, which, being comparatively little soluble, crystallize out more or less completely. To cool syrup at 26°–35° B., contained in a suitable vessel provided with means of stirring its contents, is added a quantity of oxalic acid equal to 63 (or even up to 252 lb.) of the crystallized acid for each 39 lb. of potassium present in the syrup operated on. The mixture is stirred till the reaction is complete (say, 1 hour), and then either allowed to rest till the crystalline oxalates of potash have settled to the bottom of the liquid, or filtered. The clear syrup is drawn off into another vessel, also provided with stirring gear, and together with the syrup separated from the magma of crystalline oxalates, neutralized by addition of milk of lime, or whiting stirred up in water. The neutral or nearly neutral syrup is then boiled, bag-filtered, and treated in the usual way.

The advantages of this process are:—That the removal of a portion of the potash allows the recovery of a quantity of crystallizable sugar, which would otherwise go to form molasses; that on neutralization by lime or chalk, a very large proportion of the iron present is precipitated and removed; that when soda salts are present in large quantities, a portion of the soda will be precipitated as oxalate with the oxalates of potash, and will be removed from the solution with them; that saccharine solutions containing a very large proportion of potash can be operated upon, since the precipitate formed on neutralizing the acid liquid separated from the oxalates of potash places no difficulties in the way of filtration.

The expense of carrying out the process is reduced to a comparatively small amount, either by selling the oxalate of potash obtained, as such, or by recovering the oxalic acid for re-employment, and selling the potash separated at the same time. For the latter purpose, the oxalate of potash may be dissolved in hot water and decomposed by a sufficiency of lime (caustic, carbonate, or chloride), and the insoluble oxalate of lime is separated from the solution of potash simultaneously produced. This oxalate of lime, together with that obtained on neutralizing the acid saccharine liquor separated from the original precipitate of oxalates of potash, can then be decomposed by sulphuric acid, and the oxalic acid thereby brought into solution. Afterwards, the oxalic acid is crystallized. The liquids containing the potash in solution can likewise be evaporated and brought into marketable form. It must not be forgotten, however, that oxalic acid is a powerful poison; and if a small quantity were from any cause allowed to remain in the refined sugar, the consequences would be most serious.

Tannin.—Gill and Martineau propose to use tannin for separating from sugar-solutions iron and other bodies, such as albumen, which are thus precipitated. For this purpose, an excess of tannin is added to the sugar-solutions, and subsequently removed by the addition of alumina. The alumina may either be precipitated in the solution, or may have been previously precipitated. The sugar-solution subjected to this process may be crude juice, or a solution of raw sugar, or drained syrups. By preference, the sugar-solution is boiled with the tannin, and then alumina which has been precipitated from a solution of alumina by means of whiting or carbonate of lime is added. After boiling, the solution is passed through bag-filters and animal charcoal, and evaporated and crystallized in the usual way.

Chloride of Sulphur.—In Eastes' process, the raw or low-quality sugar is dissolved, clarified, and tempered with 2–8 oz. of chloride of sulphur to 100 gal. of liquor, or the same proportion of any compound of chlorine of sulphur, or sulphide of lime, or chloralum, according to the quantity of albuminous matter contained in the liquor. After clarification, the liquor is allowed to subside, and passed through the vacuum-pan in the ordinary way. For extracting the crystallizable matter from molasses, the latter is heated and tempered as follows:—If recently-made molasses are treated, one of the agents simply is used; in the case of molasses that has been made for a considerable time, and contains free acid, sufficient alkali is used in addition.

Alcohol.—Duncan and Newlands propose to treat raw or low-class sugar by alcohol (ethyl or methyl alcohol, or methylated spirit). The sugar, containing more or less uncrystallizable sugar, is agitated in a close vessel for about ½ hour, with a considerable quantity of alcohol, as near the boiling-point as possible. About 3 gal. of alcohol to 10 lb. of sugar is usually sufficient. The alcoholic solution is then separated by decantation, filtration, or a closed centrifugal machine, and allowed to cool, when the greater part of the uncrystallizable sugar and other matters are deposited. The alcoholic solution is next separated from this deposit, in a similar manner, and is then reheated and re-used for the purification. After the alcohol has thus been alternately heated, used for washing sugar, and cooled several times, it is distilled, to separate it from water and other impurities. The sugar deprived of its impurities is heated with or without water in a still, so long as any adhering alcohol distils over.

The principal advantage of this mode of employing alcohol over those previously proposed, is that by alternately heating and cooling, the same alcohol can be made to serve several times without distillation, instead of its having to be distilled after every operation.

Sucrate of Lime Process.—This process, which has been successfully worked both for refining raw cane- and beet-sugars and for defecating cane-juice, was invented about 1865 by Boivin et Loiseau, of Paris. Successive improvements have since been made by the original patentee and others. The process effects great purification of sugar-solutions by means of a compound of sugar and lime, denominated "sucrate of hydrocarbonate of lime," formed in syrups which have been treated with calcium hydrate and submitted to the action of carbonic acid gas; but careful manipulation is necessary to ensure the desired result. When the compound is treated as will be afterwards described, it produces a very flocculent precipitate, which, in subsiding, carries with it, mechanically or in chemical combination, most of the colouring matters and other impurities present in the juice or unrefined sugar. The process depends mainly upon this peculiar decomposition of the sucrate of hydrocarbonate of lime, and on the difference in solubility of the several sucrates of lime in saccharine solutions.

Chemists have long known that sugar is capable of acting the part of a weak acid and combining with bases. With calcium hydrate, it forms a series of compounds known as calcium sucrates, all of which when suspended in water are decomposed by carbonic acid gas into calcium carbonate and sugar. When a proportion of calcium sucrate (say 5–10 per cent.) is formed in a fairly concentrated solution of cane-sugar, and partly but not entirely decomposed by passing carbonic acid gas, a compound is formed containing calcium hydrate, sucric acid, and carbonic acid chemically combined. This compound is the sucrate of hydrocarbonate of lime of Boivin et Loiseau; but if the current of gas is continued too long, this compound is decomposed, and calcium carbonate and sugar result.

The following table gives the density of lime sucrate solutions:—

Per cent. of Sugar.	Density of Sugar Solutions.	Density when Saturated with CaO.	The Sucrate Solution contains in 100 parts:	
			CaO.	Sugar.
2·5	1·018	1·026	15·3	84·7
5·0	1·027	1·040	16·9	83·1
10·0	1·036	1·053	18·1	81·9
12·5	1·044	1·067	18·3	81·7
15·0	1·052	1·080	18·5	81·5
17·5	1·060	1·092	18·7	81·3
20·0	1·068	1·104	18·8	81·2
22·5	1·075	1·116	19·3	80·7
25·0	1·082	1·128	19·8	80·2
27·5	1·089	1·139	19·9	80·1
30·0	1·096	1·148	20·1	79·9
32·5	1·103	1·159	20·3	79·7
35·0	1·110	1·166	20·5	79·5
37·5	1·116	1·175	20·8	79·2
40·0	1·122	1·179	21·0	79·0

When concentrated, this sucrate of hydrocarbonate of lime is a thick gelatinous mass (semi-solid), which when cold is sufficiently firm to be cut with a knife like jelly, but not sufficiently solid to prevent its being conveyed through pipes. Its chemical characteristics are as follows:—Treated by excess of carbonic acid gas, it is readily decomposed into calcium carbonate and sugar; heated above 100° (212° F.), it darkens in colour owing to the formation of caramel; cautiously dried below 100° (212° F.), it forms a whitish friable powder; boiled with impure saccharine liquors, it combines with a large proportion of the impurities present, and is partly decomposed. There are at least 3 chemical compounds closely resembling it, the main difference being in the proportion of sucric acid which has been replaced by carbonic acid. But the appearance of the 3 compounds when moist is not materially different.

The process of refining by means of this compound has been carried on for some years in a refinery in Paris, and in one or two in England; but its use is not very extended. It was adapted by Tooth to the purification of cane-juice at a central factory in Queensland, and is at present being successfully worked there in two instances. The mode in which it is carried out in the case of cane-juice is as follows:—

1. Crushing and Liming.—The canes are crushed the same day as they are cut, and the juice flows from the mills into tanks containing well-burnt caustic lime previously slaked with water to the consistency of a paste, and is constantly agitated to ensure thorough admixture with the lime;

when the tank is full, the proportion of lime is made up to 1–1½ per cent., and the whole is thoroughly mixed. These operations are carried on at the plantation, and the juice is then pumped through pipes, in some cases several miles in length, or conveyed in tank-barges, to the central factory; agitation being continued during the pumping, the pipes do not choke.

2. Reliming.—When the juice is received at the factory, a further proportion of slaked lime is added; if it is from good sound canes, about ½ per cent. suffices, but if from unripe or damaged canes, a larger quantity of lime is used. The store-tanks in which the juice is received are mostly made of concrete or of iron; they are of large capacity (30,000–50,000 gal.), and fitted with agitators worked by machinery, which keep the lime constantly suspended. If properly agitated, the relimed juice can be kept for several weeks without undergoing any decomposition. It is now ready for gasing.

3. Gasing.—A kiln is constructed for obtaining carbonic acid from the calcination of limestone; the lime is afterwards used for liming the juice, and the carbonic acid gas is drawn off by pumps or exhausters. The kiln is constructed to burn continuously, the limestone being fed in from the top. The products of combustion are drawn away through a 16-in. wrought-iron pipe, and cooled and washed by passing through a couple of scrubbers, so that the temperature of the gas when used is not more than 18°–24° (65°–75° F.). The lime taken from the kiln is carefully hand-picked, and, for the preparation of the sucrate, only those lumps are slaked which are properly burnt, and free from the mineral matters introduced by the fuel used in the kiln. The limed juice in quantities of 1000–1500 gal. is pumped into tanks, called *émousseurs*, of 5000–7000 gal. capacity, provided with revolving stirrers consisting of a hollow vertical shaft fitted with hollow arms, arranged to revolve in a horizontal position within a short distance of the bottom. The hollow shaft is connected with the exhausters by which the carbonic acid gas is being drawn from the kiln; and the hollow arms are perforated with a series of holes, so as to allow the gas to escape within a few inches of the bottom of the *émousseurs*. This hollow agitator is kept in rotation by machinery, and the tanks are ⅙ filled with relimed juice, which must be cool.

Carbonic acid gas is then forced under pressure in a rapid stream through the juice. At first, the liquid froths excessively, the froth frequently rising nearly to the top of the tank; to modify this, the vertical shaft is fitted with rakes, which revolve with it and break the froth. The appearance of the juice is carefully observed, and a point is at length reached when the froth commences to subside. This is the indication of the approach of the completion of the first gasing, and the current of gas is then stopped, the agitation being continued, and a small sample of the juice drawn off for testing, as follows.

A sample is rapidly boiled and filtered while hot, the amount of clarification being noted by the appearance of the liquor, which should be then of a pale straw-colour.

The appearance of the partially decomposed precipitate of sucrate of hydrocarbonate of lime on the filter is examined. If too gelatinous, it indicates that stronger sucrate is present in the compound than necessary, and that more carbonic acid must be added in order to eliminate a larger proportion of the sugar. If, on the contrary, the precipitate is granular, the liquid of a dark sherry-colour, and all or nearly all the lime has been precipitated as carbonate of lime, too much gas has already been passed. The degree of alkalinity of the juice is also ascertained by titrating it with sulphuric acid, which affords a fairly effectual check on the amount of lime still left in solution. This quantity, if the process has been carried out successfully, is ·15–·2 per cent., varying within small limits, according to the richness of the saccharine juices, and the quantity of glucose which they contain. The point which it is desired to reach by this process is such that the quantity of sucrate of hydrocarbonate of lime in solution is sufficient to ensure that, during the subsequent processes, the impurities present in the juice shall be effectively carried down; but any excess over this quantity not only incurs loss of sugar, but increases the difficulty of filtration.

4. Boiling.—When the liquor is successfully gased to this extent, it is run down from the *émousseur* into a circular closed vessel heated by steam, in which it is rapidly boiled for a few minutes. This boiling precipitates certain compounds of lime and sugar, probably in the form of basic sucrates of lime mixed with carbonate of lime and with nearly the whole of the impurities contained in the juice. This precipitate contains also a small proportion of the undecomposed sucrate of hydrocarbonate of lime.

5. Filtering.—After boiling, the hot juice containing the precipitate and the precipitated impurities is run into a *monte-jus*, and forced by air or steam at a pressure of 40–50 lb. a sq. inch through filter-presses. These vary little from those in ordinary use, and commonly called "yeast presses." The mode of filtration is simply to force the precipitated liquor into a press until all the partitions, or "leaves," as they are technically called, as shown in Fig. 1313, p. 1848, are full of precipitate. This is known by the liquor ceasing to run from the taps of the presses. If the process has been properly carried out, the liquor will filter very rapidly, leaving the presses full of a good firm cake containing 9–12 per cent. of sugar, which can readily be removed by washing in the press (by a special arrangement) with boiling water and steam. In a juice-factory, it is found

better to reject this sugar than to incur the trouble and expense of recovering it, more especially as the wash-waters are weak in sugar, and contain some impurities dissolved from the cake; they therefore require considerable evaporation before the contained sugar becomes available. In practice, for every 100 lb. of lime added to the crude juice, there will be about 250 lb. of molaxa; as the proportion of lime used seldom exceeds 1½–2 per cent. on the juice, the loss of sugar incurred would be neglected in a cane-growing country, where the actual cost of the canes forms by far the smallest portion of the cost of the manufactured sugar. The filtered juice as it runs from the taps in the filter-press is perfectly bright and clear, of a light straw-colour, and slightly alkaline to test-paper. It is now submitted to a second gasing.

6. Second Gasing.—The clarified juice while still hot is pumped into tanks and regased, whereby a further quantity of lime is precipitated as carbonate of lime. The gasing is continued until the liquor is supersaturated with carbonic acid gas; the liquor is then boiled by steam-coils or otherwise, and run into subsiding-vessels, after which the supernatant liquid is filtered, generally through Taylor's bag-filters, and is ready for concentration, if sugar of low quality is required, or for treatment with animal charcoal. The produce of sugar obtained is better in quality and quantity if char is used, and one of the remarkable features of this process is that the quantity of char necessary is only ⅓–¼ of that which is required in the ordinary refining processes. After passing through the char, the juice is ready for concentration and crystallization. In some cases, it is considered desirable to re-treat the molasses, i. e. to carry them through the same routine again.

It will be apparent that the process is one of unusual complexity, and requires careful supervision, more careful, in fact, than most chemical processes. The advantages claimed for it are:—(1) Increased sugar-yield from a given quantity of juice, (2) improved quality of sugar, (3) reduction in size of charcoal plant, (4) decreased yield of molasses. On the other hand, it is evident that for a colonial sugar-house the following disadvantages will be found:—(1) The plant is expensive; (2) the labour required is of a high class, and skilled chemical supervision is essential in order to ensure correct and successful working; (3) when the juice is impure or from unripe canes, and contains much uncrystallizable sugar, a large proportion of glucate of calcium is formed, which, on account of its solubility, goes through all the stages of the process. The greater part of this glucate is thrown out in the molasses, but a small trace of it remains in the crystal sugar, and causes it to deliquesce and to have an offensive odour. When the proportion of glucate becomes high, it forms a sticky mass, which prevents a considerable proportion of the sugar from crystallizing out after the boiling of the syrups. It is stated that the best results hitherto obtained are:—From every gal. of sound juice at 10° B., nearly 1·5 lb. of pure crystallizable sugar have been extracted; but the molasses is so heavily charged with calcium salts as to be only fit for producing a very coarse spirit. It is especially necessary in this process to guard against the slightest tendency to fermentation, for when once ferment germs have been introduced, it is quite impossible to form the precipitate of hydrocarbonate of lime. When this is the case, the precipitate thus formed is of a slimy character, which clogs the filters so that no amount of pressure will force the liquor through the press.

Although such satisfactory results have in certain cases been obtained by this process, there is little doubt that it is too complicated for ordinary plantations, and must be much simplified before it will come into general use, except in large central factories capable of treating at least 30,000–50,000 gal. per diem.

For Refining Sugar.—Although the clarification is carried out in the same way, and similar chemical reactions take place in the precipitation of the impurities, yet the mode of conducting the process is necessarily somewhat different. It is essential to successful working that the raw sugar to be operated upon should contain only small proportions of uncrystallizable sugar, certainly not more than 6 per cent.; for this reason, beet-sugars are more easily refined than cane-sugars, and it is sometimes advisable to mix the two. Commercially, the standard quality of the raw sugar is kept up to a certain definite percentage of available sugar. This is done by analysing each parcel of sugar, and mixing so as to enable the refiner to work for one week or more on raw sugar of a constant composition. The standard of available sugar preferred is generally high, say 80–85 per cent., with a proportion of uncrystallizable sugar not exceeding 2–3 per cent. The method of working may be best described under the following heads:—(1) Melting the raw sugar, (2) preparing the sucrate, (3) application of the sucrate, (4) proportion added, (5) filtration, (6) regasing the filtered liquor. The raw sugar is melted in an ordinary blow-up, fitted with copper coils, so that closed steam is used instead of live steam, as in the ordinary method of refining. The sugar is melted with water to a density of 27–30° B. (cold). The thick sucrate is prepared by dissolving good beet- or cane-sugar, which should contain not less than 90 per cent. of available sugar, in cold water to 22° B. The quantity of crystallizable sugar in this solution is determined, and ⅕ of its weight of freshly-burnt caustic lime is slaked to a thick paste with water and added; the solution is kept cool and constantly stirred, and is pumped in quantities of say 1000 gal. to the *émousseurs*, and gased in a similar manner to cane- or beet-juice, except that in this case it is not necessary to have a revolving shaft, and the rakes can also be dispensed with, as the amount of frothing is less than in the case of low-density liquors: in fact some sugar-solutions do not froth at all. Fixed perforated pipes laid along the bottom of the tank supply the carbonic acid gas from the lime-kiln, and the gasing is continued until the liquor becomes thick and gelatinous from the formation of sucrate of hydrocarbonate of lime. The exact point at which nearly the whole of the crystallizable sugar is chemically combined with lime and carbonic acid is ascertained by the appearance of the substance, and its alkalinity to test-paper. It is important during this part of the process to keep the liquor as cool as possible, and the temperature should on no account be allowed to rise above 29½° (85° F.). The appearance of the sucrate is that of a cream-coloured gelatinous mass of the consistency of strong jelly; its chemical composition is—$3\,CaCO_3, C_{12}H_{22}O_{11}, 3\,CaO\,2\,H_2O$. It is discharged from the gasing-tank through a slide-valve into a gutter or pipe communicating directly with the blow-up, or into a reservoir placed underneath in such a position as to allow the sucrate to be readily run into the blow-up.

The reservoir into which the sucrate is discharged is made of a size to act as a measure of the quantity to be added to the raw liquor. Experimental tests are made with the sucrate to discover the right proportion to add to the raw sugar liquor, so as to obtain the best clarification with the greatest possible speed of filtration. It is sometimes necessary to determine the sp. gr. of the sucrate, and add the proportion by weight, as it not unfrequently happens that numerous bubbles of gas remain entangled in the gelatinous mass. The required proportion is added either to the liquor in the blow-up, or at the time of melting, running the sucrate in while the raw sugar is being melted. The proportion added varies greatly with the quality of the sugar and the strength of the sucrate formed, but it may be taken generally that 2000 gal. of liquor at 27° B. require 200–500 gal. of sucrate for clarification.

After mixing with the sucrate, the liquor is pumped into the heater and boiled rapidly, and then forced by steam or air-pressure from a *monte-jus* at a pressure of 50–60 lb. a sq. in. through the filter-presses. The filtered liquor, freed from impurities, and very slightly alkaline, is regased, boiled, and refiltered, and is then ready for passing through animal charcoal, which easily removes the small amount of colouring matter and impurities left.

On account of the large percentage of sugar which the molaxa or cake contains (25–30 per cent.), it is necessary to re-treat with water, either in a mortar-mill, in which case it is of course necessary to refilter, or better to wash the cake in the presses by means of steam and water, which can be readily done, so that the cake contains no more than 1–2 per cent. of sugar, the resulting sweet waters being used in the blow-ups for melting the sugar.

The advantages claimed for this process are—decreased cost of working, great saving of animal charcoal, and increased yield of sugar. From the success which it has attained in England and on the Continent, it is evident that, although somewhat complicated, it can successfully compete with the commoner systems. The great drawback is that with cane-sugars of low quality, much difficulty and uncertainty is experienced in working, partly on account of the large proportion of uncrystallizable sugar, also from the fact that the soluble salts of lime formed seriously retard the crystallization of the sugar. With beet-sugar, this objection does not hold good, and it is probable that this method or some modification of it will in the future supersede to a great extent the present processes.

Elution.—In the elution process (see pp. 1859–60), a sucrate ("saccharate" or "melassate") of lime is first formed, and then purified by the action of alcohol. For this purpose, Duncan and Newlands add to an aqueous concentrated solution of any compound of sugar with lime, a quantity of alcohol, and agitate the mixture for a short time, when the sucrates of lime are mostly precipitated, and can be separated by decantation or filtration. Good results are attained by an admixture of 1 vol. of the concentrated solution of sucrate with 2 vol. of alcohol. The deposited sucrates after separation may be washed with alcohol to further free them from saline and other impurities; sufficient water to dissolve the sucrates is then added, and the mass is heated in a still, to recover any adhering alcohol.

The purified sucrates may be decomposed by carbonation, or by the action of dilute sulphuric acid of sp. gr. 1·182, whereby the lime is precipitated, and the sugar is rendered available. The alcoholic solution remaining after the precipitation and separation of the sucrates is heated in a still until all the alcohol comes over.

They also purify by means of alcohol, the peculiar compound of sugar with lime and carbonic acid known as "sucro-carbonate of lime." This substance, prepared by Johnson's, Murdoch's, or other process, is washed with alcohol, to remove saline matters and other impurities. The purified sucro-carbonate is then heated with water in a still, to separate adhering alcohol, and is lastly decomposed by carbonation, or by the action of sulphuric acid of sp. gr. 1·182.

They further remove lime salts, produced by the action of lime upon saccharine solutions containing uncrystallizable sugar, by alcohol. The saccharine solutions are heated with sufficient lime to destroy any uncrystallizable sugar present (a quantity equal to the uncrystallizable sugar is sufficient), the syrup being afterwards preferably neutralized by carbonation; the syrup, now containing a quantity of lime salts, is concentrated, after which, alcohol is added, and a large part of the lime salts is precipitated. About 2 gal. of alcohol to 10 lb. of syrup gives good results. In this manner, syrup may be freed from uncrystallizable sugar without permanently increasing its saline constituents. The precipitated lime salts are separated by decantation or filtration. The alcohol contained in the syrup, and that adhering to the deposited lime salts, is recovered by distillation.

In the elution process as ordinarily conducted, the washing of the sucrate with alcohol occupies considerable time, and involves the use, even in a small factory, of a number of elutors of large dimensions. These inconveniences Newlands avoids in the following manner. In lieu of the ordinary atmospheric temperature for the elution of the sucrate, he employs alcohol at an elevated temperature, by which means the operation is performed in a very short time, and with the aid of small plant, whilst the results are equal, if not superior. With alcohol at 74°–77° (165°–170° F.), the washing may be performed in a few minutes. The alcohol may be heated by means of steam-jackets. After the washing, the purified sucrate is further treated in the usual manner.

The alcoholic solution containing the impurities is distilled to recover the alcohol, and the remaining residue, which contains a considerable quantity of sugar, is converted into sucrate of lime by any of the usual methods, and washed with alcohol at 74°–77° (165°–170° F.), by which means a large portion of the sugar is recovered.

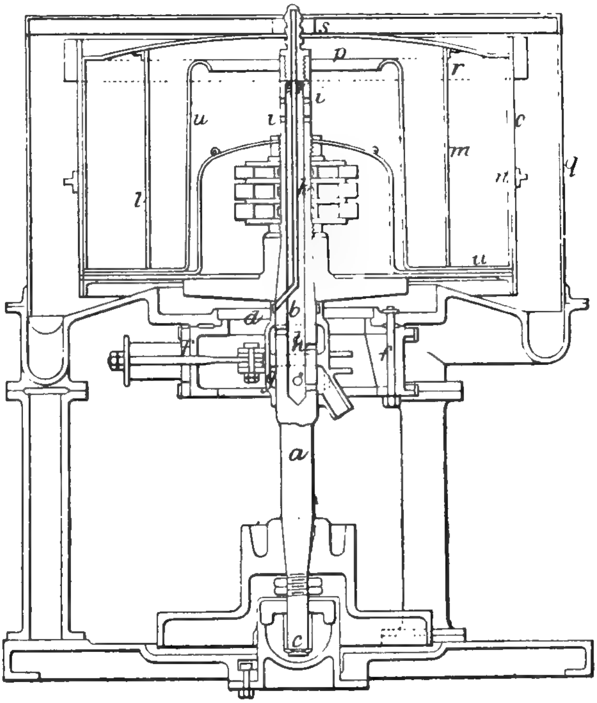
Centrifugals.—Ordinary centrifugals for curing raw sugar have been already described (see p. 1900).

Those used in refineries do not materially differ from those used in factories, except they are made of larger diameter, and therefore capable of holding a much larger quantity of *masse-cuite.* The time occupied in centrifugalling a charge of first crystal *masse-cuite* is 2–6 minutes, including washing or liquoring; the quantity of sugar turned out depends entirely upon the size of the machine, generally a turn-out of one or more cwt. of refined sugar constitutes a fair charge. The *masse-cuite* should be fed into the centrifugal a few moments after the latter has been started, but before it has attained its full speed. The syrup from centrifugals, if sufficiently pure and free from colour, is diluted to 30° B., and boiled for second crystals. These are smaller, and obtain a sale as such; occasionally, however, a special mechanical appliance is attached to the vacuum-pan, by means of which a quantity of these crystals can be drawn in during the boiling of the liquor, and after the pan has started (but before grain has been obtained), without destroying the vacuum. These crystals are fed in the usual way, and any slight colour or blemish which they may have had is coated over with the sugar deposited in increasing their size. After two boilings, the syrup again becomes discolored, and contains the whole of the mineral and organic impurities. These syrups are reboiled to a "jelly," run into coolers, and, after standing one or two days to crystallize, are centrifugalled in machines capable of holding 10–20 cwt. The sugar obtained, which of course has considerably decreased in yield, is of a light-yellowish colour, soft, and having little or no grain, and is known under the name of "refiners' pieces." The yield depends entirely upon the quantity of available sugar which the *masse-cuite* contains, but generally amounts to 20–40 per cent. of the weight of the *masse-cuite.* The final syrup is boiled, and allowed to stand in coolers for some weeks, in order to obtain the whole of the sugar capable of crystallizing. It is machined, and forms a lower quality of "pieces," or, if too bad for this, is sent to the blow-up to be again passed through the refining operations. Generally it requires three or four crystallizations before the whole of the sugar is obtained. The residual syrup or molasses is highly charged with impurities, and is either sold as such, or partially purified, and inverted by treatment with acid, as described on pp. 1915–6, and sold as brewing sugar.

Duncan and Newlands dispense with the direct action of steam, as sometimes employed, and subject the sugar contained in the centrifugal to the action of a spray produced by causing steam or air to act upon water, saccharine solutions, or alcohol, in such a manner as to diffuse them in a fine state of division; and construct the centrifugal with a hollow spindle for this purpose. Fig. 1410 shows a vertical section of the machine. *a* is the hollow spindle, with a passage *b* for the introduction of the spray, turning in a footstep-bearing *c*, and working in a bearing *d*, carried by a projecting bar *e*, secured to the frame *f* in such a manner as to admit of the requisite freedom of movement of the machine, whilst retaining the bearing *d* firmly in position. This bearing is recessed on its interior, so as to form an annular duct *g* for the admission of the spray, which is thence conducted into the passage *b*, through apertures *h*, and is discharged into the sugar through other perforations *i*, formed in the sides of the spindle, or in the top. The central pipe *k* is provided for lubricating the bearing *d*. The removable casing, constituting a core around which the sugar is introduced, is constructed with sides of the cores *l* perforated; and the core is retained in the machine after charging, the spray passing through the sides of the core into the charge in the annular space *m* between the exterior of the core *l* and the interior of the lining *n* of the drum or cage *o*. The lid *p*, attached to the drum *o* instead of to the outer casing *q*, entirely covers the drum *o*, and is provided with an annular rim *r* to encircle the upper end of the core *l*, the lid *p* with the core *l* being together retained in position by a nut *s* screwed into the threaded upper extremity of the spindle *a*.

Sugars cleansed in centrifugal machines by steam admitted to the inside of the drum are apt to have a grey appearance. Boegel and Gill found this to result from particles of dust lodging between and on the crystals of sugar, this dust being carried in by the air which is drawn through the centrifugal. To remedy this defect, the casing by which the revolving drum of the centrifugal is surrounded, is covered at top by a lid, whose under side carries a hollow casing, called the "distributor," which enters and occupies the greater part of the central space of the revolving drum. Means are provided for forcing into the interior of this distributor either moist or dry, warm, clean air. The air escapes into the lower part of the drum, and is thrown against the wall of sugar. When a charge of sugar has been filled in, the lid is lowered, the drum is revolved, and warm, moist, clean air is forced into the lower part of the drum. When the sugar has arrived at a clean crystalline state, the warm moist air is replaced by warm dry air, and the sugar is thus quickly dried. The movement of the drum is then arrested, the cover is lifted, and the sugar is cut out.

1410.



Many other processes have been from time to time employed for the purpose of dispensing with the use of charcoal. Weinrich's machine, which consists of a covered centrifugal described on p. 1934, Fig. 1410, is in use for freeing beet-crystals from some of their objectionable salts; it has been applied also to cane-sugars, and answers fairly well when the sugars are grainy in character; but for soft raw sugars containing much molasses, the time occupied in purifying the sugar, and the great loss of weight caused by the steam melting the fine grains of sugar, render it of little value except under peculiar circumstances. The yield with raw non-grainy sugars is 50–60 per cent., and the time occupied in purging a charge of 300 lb. sugar is 40–50 minutes. Raw sugar containing about 80 per cent. of crystallizable and 6 per cent. uncrystallizable would yield about 50 per cent. of sugar in hard blocks, of a dirty grey appearance, polarizing say 96 per cent., but containing a considerable proportion of the mineral impurities, with probably not more than 1 per cent. of uncrystallizable; the remainder of the crystallizable sugar has been melted by the action of the steam, and carried into the molasses. This process is at work in the refinery of James Duncan, for purifying beet-sugars, and at the Oriental Refinery, Hong-kong.

Where raw sugars are prepared by melting and graining in the vacuum-pan, and passed through this machine previous to being refined by charcoal in the manner already described, it is necessary to first grain in the vacuum-pan, otherwise the objections to the process when used for soft sugars, already urged, hold good. Of course, the larger the crystals, the less time does it take to purify, and consequently the greater the yield. Refining by successive crystallizations is of little or no value. It is carried out by melting the sugar, boiling for grain, centrifugalling, and reboiling the successive syrups. Only three crystallizations can be obtained by this plan, and the third is almost as bad if not worse in colour than the original sugar. About 50 per cent. of the total sugar is obtained from the first *masse-cuite*, 16–20 from the second, and 8–12 from the third, the molasses being fit for nothing except distilling.

Summary of Patents.—A short summary of the various patents which have been taken out for the manufacture of sugar, and for the various processes connected therewith, affords a convenient mode of tracing the progress of inventions in this industry, and of indicating what processes and methods tried by previous inventors have not proved commercially satisfactory, or have failed to secure acceptance by practical manufacturers and refiners. These notes will include some processes which, even after the patents have lapsed, have come into use, but they will not include second or third repetitions of a patent.

Since the commencement of the patent law, nearly 900 patents have been taken out for different processes, apparatus, and methods in connection with the manufacture or refining of sugar. These will be divided into classes, eliminating all such as show no clear novelty, or indicate nothing upon which a fresh invention can be readily based. A large number of processes which seemed to promise good results have failed when brought into actual work; and although sometimes a following inventor has improved a little on the original, it is impossible in every case to enter into the details essential to show in what points the subsequent improvement differed from it. Several of the most successful processes in use at present in sugar-refining do not appear at all in the records of the Patent Office, and some of the lapsed patents contain the elements of what have subsequently proved valuable processes. The summary will therefore consist of short notices only of patents in which novel ideas are put forward.

1. *Treatment of the Sugar-cane.*—The current systems of extracting cane-juice are described on pp. 1873–83. The methods which have been proposed for the purpose of more fully extracting the juice are:—

1848, No. 12033, Newton: cutting the sugar-cane into small pieces, afterwards dried in a kiln, and pulverized so as to facilitate the extraction of the sugar from the powder. This cutting and pulverizing has been repatented on various occasions since.

1853, No. 1243, Manfold and others: reducing canes to "saw-dust" by means of circular saws, and then pressing the juice out with the aid of live steam to dissolve the soluble matters. This also has been repeatedly patented since, but the mechanical power required has proved too great.

1876, No. 3539, Murdoch: cutting the canes into thin slices at an angle of about 45° to the length of the cane, grinding them between rollers of peculiar construction (the surface being cut with helical or screw threads in reverse directions, in order that the thin slices might be disintegrated), and afterwards subjecting the pulp thus obtained to pressure for extracting the juice.

None of these peculiar processes seem to have come into practical use.

2. *Evaporating Apparatus* (see pp. 1854–7).—A large number of patents have been taken out for evaporating sugar-liquors by supposed economical methods:—

1871, No. 4130, Wyatt: rotating discs, cylinders, or tubes, the lower part of which dip during the rotation into the vessel which contains the boiling juice or liquor, while the upper part is exposed to the air. This idea has been patented many times with slight modifications; the main difficulty in connection with its use is that the sugar dries on to the discs during the rotation in the form of a concrete or almost gelatinous mass, containing a large proportion of inverted sugar.

1845, No. 10474, Gadesden: an apparatus almost identical with Wyatt's.

1862, No. 1242, Fletcher: another similar one.

1865, No. 418, Fryer: the first step towards what is now known as "Fryer's Concretor" (see pp. 1898–1900).

1867, No. 3721, Tooth: a scrubber similar to that ordinarily used for gas-works. Obviously this would only be applicable to dilute solutions; if concentrated solutions were used, the packing of the scrubber would become coated with the sugar, and the sugar would be destroyed or inverted.

1868, No. 796, Tooth: the application of an exhaust to this scrubber, with arrangements for heating the lower part, to facilitate the evaporation.

1870, No. 1900, Johnson: a series of vacuum-pans placed on ascending levels so that the vapour rising from the lowest might be used as the heating agent for the one next above, the series comprising a multiple-effect (see pp. 1895–8).

1877, No. 3477, Fryer: improvements on his concretor, which have come into practical use to a considerable extent (see pp. 1898–1900).

Vacuum-pans.—The more modern forms of these are described on pp. 1893–8. As at present worked, they are used for almost all classes of raw and refined sugars.

The inventions to be referred to now mainly relate to the earlier stages, but it does not appear from the patent records that any one specifically patented the vacuum-pan itself or claimed its use as a distinct invention. All that is evident is that step by step improvements have been made in the mode of using it, or in the appliances connected with it, without anything to indicate to whom the invention originally belonged, as far as its application to sugar is concerned.

1867, No. 2213, Gordon: a discharge-chamber fixed to the bottom of a vacuum-pan in the form of a pocket, with the object of allowing the removal from time to time of the heavier crystallized portions of the sugar settled at the bottom, without the admission of atmospheric air and consequent destruction of the vacuum.

1871, No. 1777, Brough & Fletcher: alterations in the air-pumps and injection-nozzle, the object being to allow the injection-jet to spread as a solid sheet of water instead of as a spray; also electro-plating the interior of the vacuum-pan, to prevent the action of the sugar-liquors upon the metal of which it was composed.

1871, No. 3232, Robertson: exhausting the pan by means of steam-jets instead of an air-pump, using the jet on the principle of the now well-known Giffard or Körting injector.

1872, No. 287, Chapman: constructing a triple-effect in which the vapour from the first pan passes into the tubes of the second, and that from the second into the tubes of the third, the three pans being placed vertically on ascending levels, and differing very little, except in the number of the pans, from Johnson's. As regards real improvements in double- and triple-effects, and in the construction of the pans, so as to get better results from the same amount of steam, there is hardly anything in the patent records worth noting, except Rillieux's (see p. 1897).

3. *Filtration.*—Considering the great importance of this process in connection with the manufacture and treatment of sugar, the Patent Office records contain singularly little information of value.

1824, No. 4949, Cleland: bag-filters 6 ft. long and 3–4 in. diameter, which practically formed the first step towards the well-known Taylor-filter now universal in sugar-refineries.

1854, No. 792, Nash: accelerating filtration of sugar-liquors and liquoring of loaves by producing a vacuum below the sugar to be filtered or liquored, or by increasing the atmospheric pressure on the top.

1856, No. 1083, Finzell and others: the use of Needham & Kite's presses, better known in their modern forms as "yeast-presses," working under pressure, for facilitating the filtration of sugar-liquors.

1863, No. 2282, Cowen: the use of a vacuum for assisting filtration of the liquor through charcoal.

Charcoal and Substitutes for it.—These form a branch of filtration.

1860, No. 212, Duncan and others: the use of internal tubes inside the retorts in which the animal charcoal is reburnt, for the purpose of allowing the gaseous products of combustion to escape more readily, and effect considerable improvements in the quality of the reburnt charcoal.

1860, No. 2104, Belton: an artificial substitute for charcoal, made by calcining a mixture of bog-peat and chalk.

1861, No. 3275, Le Plat: revivifying animal charcoal by a wet process, consisting in washing with boiling water and milk of lime, and treating with live steam until the disengagement of ammoniacal vapours entirely ceases; also the addition of bibasic phosphate of lime or phosphate of magnesia to the revivified charcoal. In some cases, he uses acid to wash out any excess of carbonate of lime, and in some cases carbonate of soda or caustic soda to remove any organic acids which might remain.

1865, No. 1409, Muller and others: a substitute for charcoal, consisting of a mixture of China-clay, whiting and charcoal, saturated with a solution of ulmate of ammonia, and carbonized.

1864, No. 2409, Gaade: an artificial refining powder made from powdered animal charcoal mixed with argillaceous earth into a pasty mass, dried and calcined before use.

1865, No. 3078, Gaade: the use of soot, carbonized blood, and carbonized flesh, mixed with clay or other suitable plastic material, and then dried and calcined.

1866, No. 258, Montclar: another mixture of soot, with vegetable or animal charcoal, coke, gas-carbon, carbonized animal matters, and other carbonized matters, all being powdered, mixed with urine or solutions of gelatine, and dried and calcined.

1866, No. 1640, Patrick: a process of revivifying spent charcoal by allowing it to ferment, and then passing carbonate of soda through it prior to washing.

1870, No. 309, Eipfeldt and another: treating the charcoal after fermentation and steaming with caustic ammonia until thoroughly cleansed.

1876, No, 2535, Lugo: treating spent charcoal with solution of boric acid, in the proportion of $\frac{1}{10}$–1 part by weight of the acid, to 100 parts of the bone-black, and afterwards calcining it.

4. *Centrifugal Machines.*—The patents under this head are not of much importance, and as descriptions of the better classes of machines are given on pp. 1900, 1934–5, few will be referred to here.

1843, No. 9898, Hardman: apparently the first patent for the use of a centrifugal machine; from Fig. 1411 it will be seen that though the idea was somewhat crude, it was a remarkably good first step towards the process now almost universally employed for draining the mother-liquor from the sugar.

1847, No. 11920, Playfair & Hull: arrangements for continuous feeding of the *masse-cuite* into the machine while it is running.

1860, No. 1981, Fryer: keeping the atmosphere inside the casing of the machine in which the drum rotates warm and damp by means of a jet of steam.

1867, No. 1178, Merrill: an arrangement for removing the charge of sugar from the machine without stopping the rotation of the cage, effected by an internal receiver furnished with a series of scrapers hanging upon pivots, so that when these scrapers are simultaneously opened by a handle or lever, the dried sugar is removed from the cage and brought into the internal receiver, which is afterwards lifted from the machine while it is running.

1869, No. 235, Lafferty & Lafferty: improvements in the mechanical details of the machines so as to provide for more effective lubrication, and to diminish the vibration in case the cage is unequally loaded; also driving the machine by cone- or friction-gearing instead of spur-gear.

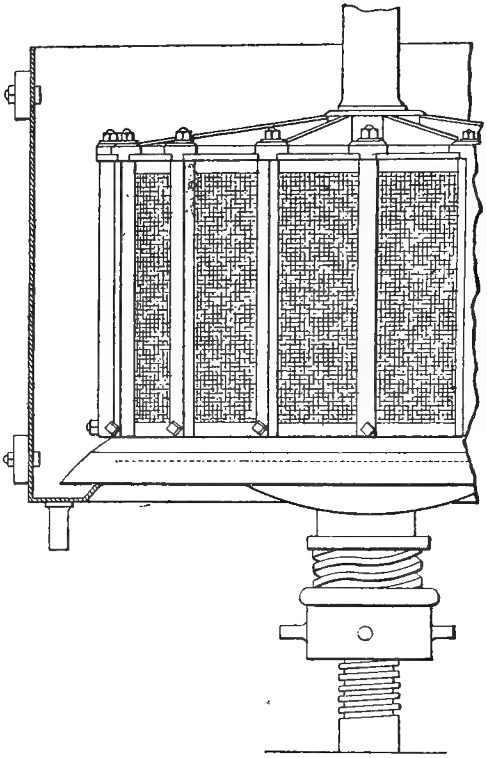
1870, No. 679, Wigner: a scoop, actuated by a slide-rest for removing the sugar while the cage is running.

1870, No. 2886, Lesware: a machine in which the basket is made removable from the spindle, so that as soon as the charge is dried, the cage may be lifted off and replaced by another containing a fresh charge.

1871, No. 3222, Lafferty & Lafferty: improvements in the friction-gear for starting and stopping the machine.

1874, No. 755, the same: further improvements, as shown in Fig. 1412, the most important having reference to providing an easy mode for discharging the dried sugar while the drum is rotating.

1411.



5. *Brewing-Sugars, Starch-Sugar, and Invert Sugar.*

1855, No. 565, Riley: manufacture of starch- or grape-sugar from starch by boiling flour or meal of any cereal with sulphuric acid under pressure, say 10 lb. a sq. in.

1859, No. 451, Garton: dissolving cane-sugar in water, and heating it to about 71° (160° F.) for 48 hours, agitating it during the first few hours, and then adding acid, which is neutralized by chalk at a later stage.

1859, No. 2138, Manbré: making brewers' sugar from a mixture of potato-starch and dextrine with rice- or maize-flour, and with diastase, malt, or sulphuric acid, and heating until the conversion into starch-sugar is complete; also defecating by lime, blood, animal charcoal, and other matters.

1864, No. 552, Manbré: use of strong iron vessels lined with lead, to serve as convertors, and raising the temperature of the starch during the process of conversion to 160° (320° F.), or say 90 lb. a sq. in., by which to avoid the formation of gummy matters and empyreumatic acrid oils; also the use of a much larger quantity of sulphuric acid, viz. 20 per cent., whereas 2–5 per cent. had been the maximum formerly used.

1867, No. 2760, Hallibone & Manbré: lining the high-pressure boilers used for conversion with lead, tin, copper, brass, silver, or platinum, by turning the edges of the sheets of metal between the flanges of the segments of which the boiler is composed, so that no portion of the iron is exposed to the action of the acid used in the process.

1869, No. 1897, Manbré: steeping barley, rice, maize, wheat, and other grains, nuts, roots, and other vegetable products in water, and masticating and grinding them for the purpose of separating the starch before submitting them to the converting process.

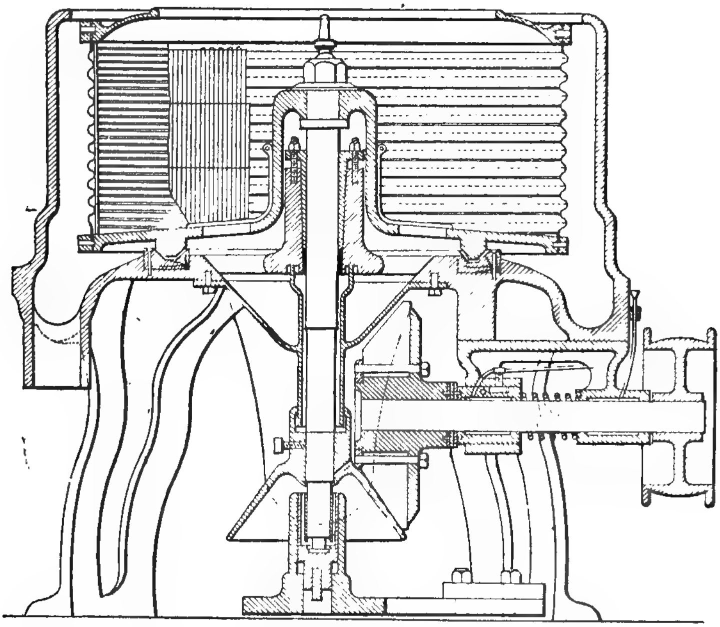
1870, No. 1562, Manbré: further improvements in the convertors, consisting mainly in the use of cast-lead linings, instead of the rolled lead previously employed.

1870, No. 205, Garton: adding to the solution in the convertor, animal char, or other substance containing phosphate of lime, so that when the excess of acids is neutralized, the precipitate of phosphates may defecate the sugary liquid.

1871, No. 1232, Garton: the preparation of brewing-sugars direct from raw cane-juice or beet-juice, by treating them with acid in the usual process of conversion, but without the juice having undergone the usual preliminary process of manufacture into sugar or syrup.

1874, No. 3639, Manbré: process and apparatus for converting starch into a mixture of dextrine and glucose, by agitating the starch with acidified water, and submitting it to dry heat over an open fire or in a stove, stirring continuously, so as to obtain a product in the form of a powder.

1412.



1875, No. 1724, Manbré: the addition of raw cane-sugar to the converted starch as it is run out from the convertor in the form of glucose, and subsequently heating the mixture in a vacuum-pan for ½ hour at a temperature not exceeding 149° (300° F.), at which temperature a chemical reaction is said to take place, producing a compound or new sugar, which is identical in sweetness and other properties with those sugars yielded by grapes and which produce the best brands of wine. After filtration, the mixed sugar can be again concentrated so as to form a solid sugar.

1874, No. 309, O'Sullivan & Valentin: the production of a compound solid body from starch or starchy substances, to which they applied the term "dextrine-maltose," and which is stated to consist of the same proportional quantities of dextrine and maltose as are ordinarily obtained from malt by the mashing process. The mode of operation is as follows:—The meal of rice or any other starchy substance, is introduced gradually, with constant stirring, into acidulated boiling water, containing 1½–3 per cent. of concentrated sulphuric acid in the proportion of 100 parts by weight of the meal to 250 parts of the acidulated boiling water, the mixture being made in an ordinary mash-tun. The transformation or conversion is arrested when the liquid contains in solution the requisite proportions of maltose and dextrine, ascertained by neutralizing the free acid, filtering, determining the sp. gr. of the filtrate, and estimating the proportion of oxide of copper reduced by the known weight or measure. The conversion is supposed to be complete when the quantity thus reduced indicates that about 44 per cent. of the glucose calculated on the total solid matter derived from the starch has been reduced. Another test given is that the transformation is complete if the specific rotatory power of the substance in solution for the transition tint is about 171°. The acid liquor is then neutralized with chalk or milk of lime until it is as nearly neutral as possible; to avoid excess of alkali, the liquor is evaporated in vacuum-pans until the compound body retains only 4–5 per cent. of moisture. It is directed that care be taken in packing the substance so as to prevent it from absorbing moisture.

1876, No. 2025, Valentin: the manufacture of "dextrine-maltose," and further improvements in the method of evaporation, consisting essentially in additional filtration, and in finishing the concentration in the open air instead of a vacuum-pan. By this change, it is claimed that the albuminoid substances which have not been removed by filtration are more completely oxidized, and that the finished article is consequently superior in quality.

6. *Various Chemical Substances.*—The number of chemical agents which have been patented for use, either in the treatment of cane- or beet-juice, or in refining and purifying sugar, is so great that space will not be occupied by always entering into the details of the manipulation proposed. In the absence of any statement to the contrary, it may be assumed, either that the experiments proved unsuccessful, or that the process was not brought to a practical trial.

1774, No. 1061, Fordyce: the use of blood for clarifying sugar.

1813, No. 3754, Howard: the use of alum, lime, and chalk (see p. 1887).

1815, No. 3912, Martineau and another: the use of animal charcoal, coke, certain kinds of ochres, and lamp-black.

1825, No. 5272, Jennings: washing raw sugar with rectified spirits of wine, or other alcoholic liquids, for the purpose of dissolving out the colouring matters and impurities.

1833, No. 6442, Terry & Parker: mixtures of sulphate of zinc, prussian blue, and lime, so proportioned as to produce what the inventors call "ferrocyanic acid." The sugar-liquor to be treated is boiled and "scummed" in the ordinary way, blood or white of eggs being used, and then the solutions containing the substances above mentioned are added while the liquor is boiling.

1838, No. 7573, Stolle: the use of alcohol charged with about 2 per cent. of sulphurous acid, subsequently washing the sugar with pure alcohol to remove the excess of sulphurous acid.

1847, No. 11790, Sievier: the use of the carbonaceous matter produced by the action of sulphuric acid on sugar as a means of purifying other sugar.

1847, No. 11991, Scoffern: acknowledging that salts of lead had previously been used for purifying sugar, claims the use of sulphurous acid for extracting the excess of lead which may have been left in the liquor; also a special mode of preparing the acetate of lead, which presents very little peculiarity (see p. 1888).

1849, No. 12617, Reece & Price: the use of hyposulphite of lime, in conjunction with acid sulphate of alumina, acetate of alumina, or similar substances; also the use of the combination of sugar and lime known as "saccharate of lime," to produce a magma of carbonate of lime and sugar, for the purpose of neutralizing the excess of acid which may have been used in any process.

1851, No. 13634, Oxland & Oxland: the use of phosphoric acid in a state of combination, for separating the residual lime or other chemicals which may have been left in the refined sugar.

1852, No. 14233, Egan: the expressed juice of the plantain for defecating raw sugar liquors or juice. The idea is doubtless taken from the custom which the natives of the Straits Settlements, China, &c., have of expressing the juice from the *Musa spp.*, diluting it with water, and using it to liquor the pots or *pilones* of raw sugar; the juice is rather acid, but it really purges the sugar very well, though it considerably reduces the weight by formation of molasses.

1852, No. 366, Nash: the use (1) of salts of tin for defecating the sugar—this has since been repatented upon several occasions; (2) of chlorine for removing or destroying the colour; (3) of ammonia for dissolving the albuminoid impurities from the sugar.

1853, No. 431, Hills: a filter of sawdust, phosphate of lime, or animal charcoal, to remove any residue of lead left in the sugar from the use of the subacetate of lead process for refining.

1853, No. 487, Brandeis: the use of salts of lead, tin, zinc, and bismuth, the only one which appears to be new being the bismuth; also removing the excess of these metallic salts through a filter of calcined shale or schist.

1853, No. 1510, Galloway: tannic, oxalic, gallic, or other acids, or combinations of these acids with potash or soda, for removing residual lead.

1853, No. 2358, Way: soluble silica to neutralize excess of lime.

1858, No. 655, Gilbee: washing the crude sugar with alcohol, and then treating it with sulphuric, tartaric, or other acids or salts.

1859, No. 58, Reynolds: the use of stannate of alumina.

1859, No. 370, Rousseau: the use of hydrated peroxides of manganese and iron.

1859, No. 1131, Reynolds: the use of meta-stannic, stannic, or tunstic acid, free or in combination.

1859, No. 1861, Possoz: the use of lime with subsequent carbonation at a somewhat high temperature, the resulting syrup being again treated with lime and recarbonated.

1861, No. 1956, Gemini: fullers' earth.

1861, No. 3112, Mennons: egg-albumen.

1862, No. 2294, Herepath: bleaching-powder.

1863, No. 2053, Dubrunfaut: the first application of the well-known phenomenon of osmosis for the separation of the organic and inorganic salts present in saccharine solutions from the sugar.

1866, No. 594, Gedge: cutting the cane or beet into small slices, and extracting the saccharine matters slowly by passing these slices successively through solutions containing less and less quantities of sugar, and finally into clean water, thus extracting the sugar by what is called the diffusion process (see pp. 1842–5, 1880–3).

1866, No. 2645, Beanes: the use of ozone.

1866, No. 3146, Jünemann: a gelatinous precipitate of saccharate of lime.

1867, No. 54, Johnson: treatment with lime and carbonic acid in a somewhat peculiar way.

1869, No. 1498, Robert: further modifications to adapt the diffusion process to the treatment of raw canes, so as to extract the saccharine matter by one continuous feeding process (pp. 1881–3).

1871, No. 1235, Duncan & Stenhouse: the use of sulphides and hydrosulphides of the alkaline earths for extracting iron from refined sugar.

1871, No. 1406, Dawlings: the use of carbonized iron ore.

1871, No. 1619: Duncan & Stenhouse: the use of sulphuretted hydrogen and calcium sulphides and hydrosulphides, for removing metallic impurities.

1871, No. 2090, Duncan, Newlands, and Newlands: the use of sulphate of alumina to remove the potash salts present in the sugar or syrup, and the manufacture of alum thereby. This process is more fully described on pp. 1927–8.

1873, No. 3151, Tamin: the use of soluble silica and fluorides.

1874, No. 1736, Johnson: the use of alkaline carbonates prior to treatment of the sugar with alcohol.

1876, No. 210, Barrault: the "sucrate" process, which is more fully described on pp. 1930–3.

1877, No. 190, Bernard & Ehrmann: the use of magnesia.

1877, No. 583, Stuart: the use of hypochlorite of sulphur.

1878, No. 2211, Barrault: the re-treatment of the first crystal sugar by the sucrate process, in order to avoid the use of animal charcoal.

7. *Sundries.*—Under this heading are included a number of patents which are not readily classified with those previously referred to. Some two or three are noted mainly because of their peculiarities, and it is quite possible in one or two cases that useful ideas may be found in them.

1852, No. 797, Bessemer: "to prevent the drying of sugar, and to render it permanently moist, by the addition of saccharine or such other matters as do not readily evaporate on exposure to the air." This addition is to be effected by adding a solution of chloride of sodium, or such other saline matters as would render the sugar solution deliquescent, or uncrystallizable, and give the requisite moisture. In some cases, gelatine or glucose is proposed for the same purpose.

1862, No. 822, Fryer: the use (1) of very large crystallizing vessels not less than 30 ft. deep, and holding 50 tons of sugar, for crystallizing the sugar contained in the residual syrups; (2) after expressing the remaining syrups from the crystals, placing the *masse-cuite* in bags, and expressing the syrup by placing the bags one on another so as to form a column 20–50 ft. high. The first part has, with modifications of the size of the vessels, come into general use in many sugar-refineries; the second portion has, after repeated trials, been abandoned by the majority of refiners.

1864, No. 1342, Bertholomey: a process of feeding the growing crystals in the vacuum-pan by successive supplies or additions of concentrated syrup or clarified sugar. The patent hardly seems to have held its ground as a patent, but the process has come into considerable use, especially with those refiners who aim at the production of large crystals.

1868, No. 1845, Linard: the first step on the patent records towards the central factory system (see p. 1836). Although the invention as described here had not been patented before, very similar apparatus had been tried previously, substantially consisting in extracting the juice of the cane or beet on or close to the spot where they are grown, and supplying the juice as expressed to a central factory.

1871, No. 1185, Weinrich & Schröder: chilling the *masse-cuite* in moulds, and afterwards moving these moulds bodily into the centrifugal machine, so that the syrup is forced out, forming a kind of crude loaf; also liquoring this sugar in the machine, by means of "warm water in a state of mist," this warm water being obtained from a jet of steam let in with air into the interior of the revolving cylinder.

1874, No. 1870, Duncan (a communication from Weinrich): the addition of ultramarine or artificial ultramarine to the powdered, crushed, or crystallized sugar, in order to improve its quality and appearance; also certain modifications of centrifugal machines, so as to render them more suitable for this process, consisting essentially in the use of an inner cylinder, so arranged as to cause the sugar to form an even layer over the drum of the machine, which, being suspended in the drum by a swivel-joint, is capable of being removed shortly after the machine has been started, and while it is running.

1875, No. 4107, Duncan & Newlands: further improvements for the same purpose; also suggestions for the use of a spray of saccharine solution or alcohol in addition to water, for washing the sugar in the centrifugal (see p. 1934).

1875, No. 4420, Körting: another form of fog or damp air washing apparatus, for use in centrifugal machine.

1876, No. 2728, Gill: purifying the air which is conducted to the interior of the centrifugal machine by freeing it from dust (see p. 1935).

1876, No. 2685, Duncan & Newlands: further modifications of the centrifugal, to dry the steam supplied to the revolving cage.

1876, No. 2305, Schwartz: liquoring the dried sugar in the machine with water at 0° (32° F.).

1877, No. 3749, the same: a process for "imparting a bloom or complexion" to the sugar, by treating white or crystallized sugar with syrup or suitable solution of some uncrystallizable sugar.

Sugar Analysis.—The complete analysis of sugar, or of cane- or beet-juice, is in most cases a problem of considerable difficulty, because in all except the most pure white sugars, some organic matters are present, consisting of inverted sugar, colouring matters, waxy substances, and nitrogenous impurities, the accurate separation of which is all but impossible. For chemical purposes, it is customary, and one may almost say necessary, to put all these bodies together under a single heading as "organic matters not sugar." By this means, the analysis of sugar is brought within the compass of ordinary commercial work, and can be executed in a reasonable time.

It will be necessary to describe separately the analysis of cane-juice and beet-juice, but first the analysis of an ordinary raw cane-sugar or a refined sugar of moderate quality may be dealt with. The determinations usually made in such analyses are (1) cane-sugar, called crystallizable sugar, (2) uncrystallizable sugar, which includes invert sugar, (3) salts or ash, (4) moisture, (5) organic matters not sugar, generally reported as "unknown organic matters," (6) insoluble constituents, if any. Sufficient description will be given of what is included under the general term "uncrystallizable sugar"; but it is desirable to point out that the "salts" may be both organic and inorganic. The latter are by far the more important to the sugar-refiner, and consist chiefly of potash and lime salts, and smaller proportions of salts of soda, magnesia, and iron. These are frequently combined in the form of sulphates, phosphates, chlorides, carbonates, and silicates; but in raw beet-sugars, saccharates of lime and potash are very common.

Some 20 organic acids have been reported to be found in combination with the bases in sugar; but only an alphabetical list of them can here be given. They are,—acetic, aspartic, apoglucic, butyric, citric, formic, glucic, humic, lactic, malic, melassic, metapeptic, oxalic, pectic, succinic, tartaric, and ulmic. The organic matters in sugar contain certain alkaloids, especially betaine, peculiar to beet-sugar; certain nitrogenous matters, mainly albumen, legumine, and ferments; and certain non-nitrogenous organic matters, such as pectose, peptin, mannite, starch, colouring material, caramel, cellulose, gum, fat, and wax. The insoluble matters consist almost entirely of accidental mechanical impurities, such as sand and clay, with small proportions of the fibrous matter derived from raw sugar.

The process of analysis may now be described, with one preliminary remark. The difficulties which occur in the analysis of samples of sugar are due more to imperfect sampling than to error in analysis, owing to the fact that most low sugars contain such a very notable quantity of moisture that it is difficult to draw small samples such as may be used for the various processes with sufficient accuracy to represent the bulk. When the sample is a dark-coloured low sugar of the Jaggery class, it may contain as much as 10 per cent. of its weight of lumps of pottery and stones, and in many cases 7–10 per cent. of moisture. Great care must be taken to ensure thorough admixture before weighing the samples on which the analysis has to be made; it is also very essential to preserve the samples in well-closed bottles to prevent loss of moisture.

Characters of Cane-sugar.—Cane-sugar or sucrose is the variety of sugar which is extracted from the sugar-cane, a plant which grows only in tropical and subtropical climates, and which at one time supplied nearly the whole of the sugar consumed in Europe. It is extensively cultivated (see pp. 1860–71), and the manufactured product, under the name of "raw sugar," forms the staple produce of many of our colonies. Until recently, both the cultivation and manufacture (see pp. 1871–1902) of this most important article have been much neglected, and even at the present day some of the largest sugar-producing countries are exporting sugar, which, from its appearance and characteristics, has evidently been sadly spoiled during preparation. Sucrose is also extracted from the juice of the beetroot; it is identical in chemical composition with sugar extracted from the cane, and a considerable quantity is produced for consumption in Europe. More care is taken in the manufacture of sucrose from beet than from cane. Sucrose is likewise contained in the juices of many other plants, notably the sorghum and the palms; its manufacture is, however, virtually restricted to the sugar-cane, beetroot, sorghum and sugar-maple in America, and a small proportion from the wild date-palm in the East. Sucrose is found associated with invert sugar in the juice of many fruits: the following table by Payen shows the percentage proportions:—

	Cane-sugar.	Total Sugar.
Pineapple (Montserrat)	11·33	13·30
Strawberry (Collina d'Ehrherdt)	6·33	11·31
Apricot	6·04	8·78
Apple, grey Reinette (fresh)	5·28	14·00
„ „ (preserved)	3·20	15·83
„ English	2·19	7·65
„ Calville (preserved)	0·43	6·25
Plum, Mirabelle	5·24	8·67
Plum, Reine Claude	1·23	5·55
Orange	4·22	8·58
Lemon	0·41	1·47
Raspberry	2·01	7·23
Peach	0·92	1·99
Pear, St. Germaine (preserved)	0·36	7·84
Pear	0·68	8·78

Sucrose separates from a supersaturated solution in the form of monoclinic prisms, generally with hemihedral faces; its sp. gr. is 1·606; it is very soluble in warm water, but insoluble in ether and absolute alcohol; absolute alcohol when warm takes up a small proportion, which is again deposited on cooling. Heated to 160° (320° F.), it melts, and solidifies again on cooling, forming "barley-sugar." At higher temperatures than this, it suffers decomposition, losing water and becoming converted into a mixture of dextrose and lævulosan; and at still higher temperatures, it is converted into caramel. Its concentrated solution can be kept exposed to the atmosphere for some considerable time without suffering any sensible amount of deterioration; in weaker solutions, however, the sucrose is gradually transformed into invert sugar, more especially if the sugar be at all impure, in which case it is very prone to undergo fermentation.

Long-continued heating converts it into invert sugar, this change being more rapidly brought about in the presence of an acid; when treated with concentrated sulphuric acid, it is transformed (with evolution of sulphurous acid and other volatile products) into a black carbonaceous mass. With bases, it forms a class of salts known as sucrates; the alkaline earths combine with it, and its optical power is reduced, not however proportionally to the quantity of the base, but to the concentration of the sugar solution. Its specific rotatory power, which does not vary with the temperature, is 73°·8 for the transition tint. Various salts have the property of preventing sucrose from crystallizing.

Sodium chloride forms with it a compound having the formula $C_{12}H_{22}O_{11}$, $NaCl.2H_2O$. Concentrated sugar solutions dissolve a large proportion of lime, forming thereby compounds containing one, two, or three equivalents of lime, which are readily decomposed by carbonic acid gas. The calcium sucrates formed by treating concentrated solutions of sucrose with calcium hydrate are four in number. As several methods have been proposed for manufacturing or refining sugar by the aid of these compounds, they may be shortly described. The monobasic sucrate ($C_{12}H_{22}O_{11}CaO$), prepared by precipitating a saturated solution of sugar containing excess of lime with 85 per cent. alcohol, forms a white precipitate which, on drying, forms a brittle substance easily soluble in water. The bibasic sucrate ($C_{12}H_{22}O_{11}2CaO$) has been obtained by Boivin et Loiseau by several methods; it is easily prepared by precipitating with alcohol of 65 per cent. a saturated solution of sucrose with excess of lime, and boiling; it is decomposed by water into the tribasic salt and sugar. Sesquibasic sucrate ($2C_{12}H_{22}O_{11}3CaO$) is formed by boiling a solution of sugar with excess of lime; the compound separates out, and may be obtained as a white friable mass by evaporation in an atmosphere of carbonic acid. Tribasic sucrate ($C_{12}H_{22}O_{11}3CaO$) is precipitated in flocks resembling albumen, when a sugar solution containing excess of lime is heated; it is readily soluble in sugar water.

The formation of the peculiar sucro-carbonate of lime, the "sucrate of hydrocarbonate of lime" of Boivin et Loiseau, has been fully described under Sugar-refining (see pp. 1930–3). The chemical composition, which, however, varies with the density of the solutions, temperature, and proportions of sugar and lime, is $3CaCO_3$, $C_{12}H_{22}O_{11}.3CaO2H_2O$.

Sucrose is not directly fermentable, but first requires inverting. When its solution is mixed with yeast, it gradually becomes converted into invert sugar, and subsequently into alcohol and carbonic acid,—

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

Other compounds are also formed, as shown by Pasteur, e. g. glycerol (glycerine) and succinic acid, amounting to nearly 5 per cent., so that the proportion of alcohol produced is only 51–51½ per cent. instead of 54·97, the theoretical quantity. The action of the yeast is not thoroughly understood. Mineral acids greatly retard fermentation, which is also prevented by carbolic and sulphurous acids.

Determination of Crystallizable Sugar.—This is now universally made by means of the polarizing saccharometer, some forms of which are more fully described hereafter. All these polariscopes are graduated, so as to require a solution of sugar of some definite strength. With those which are most frequently used, viz. the Penombre and the Duboscq, the graduation is made for a 16·35 per cent. solution of sugar. The process will be described on the supposition of this being the required strength. Tables are given with the various instruments, and instructions as to the normal quantity of sugar to be taken.

The special apparatus required consists of weights weighing 16·35 *grm.* (the normal quantity), others for 13·175 *grm.* (the half-normal), and measured flasks having 2 marks on the neck, which is greatly elongated to allow of this. The lower mark represents 100 *cc.*, and the upper 110 *cc.* In addition to these, it is useful to have one or two flasks containing 150 *cc.* to the lower mark and 165 *cc.* to the upper. The balances should be capable of weighing this quantity within 0·01 *grm.*

To prepare a liquid for polarization, proceed as follows. Take a counterpoised basin provided with a lip well adapted for pouring, and weigh 16·35 *grm.* of the sample to be polarized. After weighing, pour about 50 *cc.* of water, preferably slightly warmed, on to the sample. As soon as the greater part of the sugar is dissolved, decant the solution into a 100-*cc.* flask, carefully dissolve out the remainder of the sugar, avoiding the addition of more water than is necessary, so as to keep the total volume of the solution below 80 *cc.* In the case of pure loaf and crystal sugars, this solution will be sufficiently clear and transparent to be capable of being polarized, and the solution may be at once made up to the full volume of 100 *cc.*; but the analysis of such samples is but rarely required, and in all other cases it is necessary to clarify the solution, in order to remove the colouring matter and render it sufficiently clear to be examined in the polariscope. This clarification is effected by the addition of an excess of a solution of basic acetate of lead, which causes an immediate precipitation of the colouring matters present in ordinary commercial sugars, and probably converts the glucose and invert sugar into salts of lead (glucate of lead), which have little or no action on polarized light. No precise rules can be given for the quantity of basic acetate of lead that is required; too large a proportion introduces error into the analysis, since it causes an increased volume of precipitate, and, according to some authorities, slightly increases the rotation of the sugar solution. With light-coloured refined sugars and pieces, 2 per cent. is generally sufficient; with darker muscovados, 3-5 per cent. is often required; and in the case of very low-grade sugars and molasses, the proportions may sometimes be as much as 7 per cent. The only guide is that enough must be added to completely precipitate the whole of the colouring matter, and the filtered liquor must be sufficiently bright and clear to enable the readings on the polariscope to be taken with ease.

After the addition of the basic acetate of lead, the flask is stoppered, thoroughly shaken and after standing until the froth has subsided, filled with cold water to the 100-*cc.* mark, and stoppered and shaken again sufficiently to mix the contents thoroughly. If the sugar is of low quality, it is generally better to add a small quantity of finely-powdered bone-black (say about ½ *grm.*), after which the liquid is again shaken. In dealing with sugars of medium colour, it is frequently a great improvement to remove the excess of acetate of lead by the use of sulphite of soda. The solution of this salt should be made of such a strength that vol. for vol. it is nearly or quite equivalent to the basic acetate of lead solution which is in use, and if say 5 *cc.* of basic acetate of lead solution have been used, 3 *cc.* of the sulphite of soda solution may be added after the flask has been shaken and before it has been filled up to the 100-*cc.* mark. This sulphite of soda effects the entire removal of the excess of lead, which is otherwise apt to become carbonated on exposure to the air, and so render the clarified solution turbid. Whichever method is adopted, the solution must now be allowed to settle, and filtered. The filter should rest in a suitable cylindrical vessel, so that the drops falling in the funnel shall be exposed but little to the air. A funnel 2½ in. diam. with a 4½-in. filter is the usual and convenient size.

The filtered solution is carefully transferred to one of the tubes of the polariscope; the long tube of 200 *mm.* length is that which is almost universally used, although for rather dark liquids a shorter one (100 *mm.* in length) is sometimes convenient. When properly filled and capped, the tube is transferred to the polariscope, and the rotation is read.

If the solution is too dark or coloured to polarize well, it is far better to weigh out a fresh quantity, and use an increased proportion of acetate of lead, rather than accept the indifferent or uncertain reading on the polariscope.

Determination of the Uncrystallizable Sugar.—This determination is less accurate than any other made in the ordinary course of sugar analysis, although with proper care the error should not amount to more than a fraction of a per cent. in ordinary cases, and 1 per cent. or thereabouts in the case of dark sugars and molasses. What is known as Fehling's solution is almost always adopted, although certain modifications have been introduced, which there will be occasion to refer to. This method depends upon the fact that an alkaline solution of sulphate of copper holding a salt of an organic acid (such as tartrate of potash), when added to a solution containing uncrystallizable sugar, and boiled, is decomposed, and a portion of copper present is precipitated in the form of cuprous oxide. The end of the reaction is ascertained, when the process is used as a volumetric one, by the disappearance of the blue colour of the solution of copper, or by the entire removal of the copper, as shown by testing a drop of the filtered liquid, previously acidified with acetic acid, with ferrocyanide of potassium. When the process is used as a gravimetric one, the precipitate is weighed as cupric oxide.

The Fehling solution is prepared as follows:—34·64 gr. of dry crystallized copper sulphate are dissolved in not more than 200 *cc.* of distilled water; in another vessel, 150 *grm* of neutral sodium potassium tartrate (Rochelle salt), to which is added 10 gr. of caustic soda (stick), are dissolved in about 100 *cc.* of water. The two solutions are mixed in a *litre* flask, diluted with water, and made up to 1 *litre* at 15° (59° F.); 10 *cc.* of this solution is equivalent to 0·05 *grm.* of invert sugar, and to different proportions of the other sugars by which it is reduced. This solution will not keep long, and on this account it is especially desirable that it should not be exposed to the light or air; but if the two solutions are kept separately, and mixed in the proper proportions shortly before use, they may be depended upon to remain unchanged for some months. Among the modifications which have been proposed is the use of ammonia, to which a small proportion of chloride of ammonium is added, and the quantity of caustic soda considerably increased; also that of Possoz, in which the quantity of sodium and potassium tartrate is greatly increased, and a large proportion of bicarbonate of soda is added; but it is doubtful whether either of these is any real improvement. In any case, it is especially desirable that pure crystallized sulphate of copper should be used, free from adhering moisture. It must not, however, be dried, except by pressing between sheets of filter-paper.

What is called the normal solution of sugar for the purpose of the uncrystallizable sugar determination, consists of 5 *grm.* of sugar made up to 100 *cc.* of solution in water. This strength answers well for most samples of raw and low refined sugars, as it will then correspond to about 0·5–0·2 per cent. of uncrystallizable sugar; but for sugars containing a large quantity of uncrystallizable sugar, the strength of the solution must be decreased, especially in the case of molasses; while for high-class crystallized sugars, it will sometimes be necessary to use a 20- or even 30-per cent. solution.

The volumetric test is carried out as follows:—A proportion of the before-mentioned solution of sugar is measured into a porcelain basin of 4 in. diam., supported on a retort-stand over an Argand burner, and diluted with about 100 *cc.* of water, and heated to boiling for a minute or two. A portion of the copper solution judged to be nearly sufficient to precipitate the uncrystallized sugar present is added from a graduated burette, and the solution is again boiled for one or two minutes. The lamp is withdrawn, and the liquid is allowed to settle. If it has attained a distinct blue tint, the proportion of Fehling solution added is too great, and it is necessary either to add a further proportion of the sugar to be tested, or to commence a fresh experiment. If, however, the solution is not blue, a few drops are removed by a pipette and transferred to a very small filter, the filtrate being collected in a suitable vessel. One drop of this filtrate is transferred to a porcelain slab or testing-tile, acidified with acetic acid, and a drop of a dilute solution of ferrocyanide of potassium is added. If a red colour is produced, sufficient copper solution has been added; if the colour is intense, or a precipitate forms, considerable excess has probably been used, and in that case the experiment should be repeated. If, however, no brown coloration is produced, more copper is required, and the few drops of filtrate are returned to the basin in which the boiling is taking place, and a further measured addition of copper solution is made. The whole is then boiled again, being previously diluted with water, if necessary, so as to prevent too much concentration; and the test with ferrocyanide of potassium is repeated in exactly the same way. These successive additions of copper are made and the tests are repeated until the drops of filtrate and ferrocyanide of potassium when mixed show a very faint coloration.

The first analysis is now complete, but as soon as the burette has been read off, it is desirable to repeat the analysis, as follows. Take another 50 *cc.* of the sugar solution, and run in from the burette a measured quantity of copper solution, to within 1–2 *cc.* of the total quantity used in the last experiment. Dilute, boil, and test the filtrate as before, and, if necessary, make successive additions of 1–2 *cc.* of copper solution, testing after each addition. The second test should be considered as the accurate one.

The gravimetric method depends upon the separation of the precipitated cuprous oxide. The process is carried out as follows. 100 *cc.* of the sugar solution are measured, and mixed with 25 *cc.* of the Fehling solution. The mixed solutions are heated on the water-bath for some minutes, and finally boiled. The solution must be examined to ensure that the copper solution is in excess, as indicated by the blue colour of the liquid. If this is not the case, a further measured quantity of the copper solution must be added. The precipitate is allowed to subside, the clear liquor is decanted through a filter, the precipitate is washed by decantation with hot water, the washings being passed through the filter, and finally the precipitate itself is washed with hot water on to the filter. The precipitate must be dried, the precipitated cuprous oxide carefully detached, the filter ignited in a spiral of platinum wire, the ashes added to the bulk of the precipitate, and the whole thoroughly ignited in a platinum crucible at a strong red heat. The residue must be moistened with a few drops of nitric acid, dried, and again ignited, and the cupric oxide weighed: 220·5 parts of cupric oxide correspond to 100 parts of anhydrous grape-sugar or dextrose. The washing of the filter free from alkali must be carefully attended to, as an error is very liable to be introduced from this cause, on account of the obstinacy with which the alkaline salts cling to the precipitated cuprous oxide, so that it is essential that the filter should be washed first by decantation, and then thoroughly with boiling water.

Brief reference must be made to one or two other methods occasionally used for the determination of uncrystallizable sugar, although not so often applied to the ordinary raw or refined sugars of commerce. In Gentele's method, when an alkaline solution of potassium ferricyanide is heated with invert sugar, it is reduced to ferrocyanide, and the yellow solution becomes decolorized. The standard solution is prepared by dissolving 109·2 *grm.* of potassium ferricyanide and 50 *grm.* of potassium hydrate in water and diluting to 1 *litre*; 10 *cc.* of this solution equals 0·010 *grm.* of invert sugar. 50 *cc.* of this standard solution are heated in a porcelain dish to a temperature of 75°–85° (167°–185° F.), the sugar solution being slowly added until the colour is discharged. The process is far more suitable for the brewing sugars commonly sold under the name of "glucose" than for ordinary raw sugars.

Determination of Water.—This is effected in the same way as the moisture of most vegetable products, by weighing a known quantity into a counterpoised watch-glass or capsule, and drying at a temperature of 101°–102° (214°–216° F.). With raw sugars of good quality, and especially large-grain refined sugars, there is no difficulty in the process, provided the temperature to which the sugar itself is actually exposed exceeds the boiling-point of water by 1° or 2°. The drying can be completed in 2–3 hours if a small quantity (1–1½ *grm.*) is taken. Some sugars, especially beet, absorb moisture so rapidly that it is essential that the cooling should take place under a desiccator, and that the drying should be repeated, and the dried sugar reweighed to see if any further loss takes place.

With low-grade sugars, such as Jaggery, and especially with molasses, the difficulty of drying is very great. It is essential in this case to reweigh 2 or 3 times. Sometimes when dealing with molasses containing a large amount of uncrystallizable sugar, and especially with molasses containing notable quantities of glucate of lime, it is necessary to add sand or powdered glass. The best method is to take a known weight of thoroughly washed and dried sand, and transfer it to a tared capsule, adding a small quantity (1–2 *grm.*) of the molasses to be examined, weighing again, then stirring the whole together with a piece of platinum wire of known weight, so as to produce an intimate admixture, and placing the capsule with all its contents, platinum wire included, in the air-bath. The temperature must be raised to at least 105° (221° F.), and the contents should be stirred with the platinum wire at intervals of ½ hour for some 3 hours, then moistened with alcohol, and redried. It will be necessary to weigh and redry once or twice, even after all these precautions; but when the loss between successive weighings falls as low as 0·2–0·3 per cent., it may be ignored, as the strong probability is that the decomposition of the sugar which is then taking place is producing a greater error than that which is caused by the comparatively small proportion of water which is not estimated. It is imperative to use a gas-regulator of some kind to regulate the heat of the air-bath. Borradaile's or Peeble's answer well for the purpose, or, if gas is not available for heating, a copper water-bath filled with the solution of chloride of calcium boiling at a temperature of 105° (221° F.) should be used instead.

Determination of Ash.—In this country and in France, it is the universal practice to return the ash as follows. It is ignited, moistened with sulphuric acid, again ignited, and weighed, and $\frac{1}{10}$ of the total weight thus found deducted. The reasons for this are two-fold: (1) the addition of the sulphuric acid facilitates the combustion of the sugar, and prevents the charred mass from becoming hard; (2) the bases present are all converted into sulphates, chlorine and carbonic acid being expelled, by which means the loss by volatilization and the error incurred by the expulsion of the carbonic acid gas at a red-heat are greatly diminished.

The ash should always be determined in a tared platinum dish of small size (2–4 *grm.* of the sugar sample are sufficient). The heat should be applied at first to one side of the platinum dish, and the flame gradually brought under the centre, so as to raise the whole to a moderate red-heat. The completion of the ignition is far more advantageously performed in a muffle, because the direct radiated heat from the top of the muffle burns off any carbon which may have assumed a graphitic character. When thoroughly ignited, the ash must be cooled under a desiccator, and weighed; the weight after deducting the tare of the dish is reduced by $\frac{1}{10}$, and calculated to per cent. on the sample. If this ash is excessive in quantity, it is frequently necessary to determine the insoluble ash as distinct from the soluble. This occurs most frequently with low sugars of the Yloilo and China class; in such cases, the insoluble impurities consist almost entirely of sand, alumina, and other such mechanical matters, and are of no more importance to the refiner than is represented by the proportion which they form of the sample. The soluble ash, on the other hand, represents those salts which pass into solution, and which hinder the crystallization of the sugar.

Sometimes it is necessary to determine the amount of alkaline salts, viz. carbonates of potassium and sodium present in the ash. This may be done accurately by executing a full mineral analysis of the sulphated ash, obtained as before described; but for commercial purposes, it is generally sufficient to adopt the following much more rapid process. The sugar is ignited without the addition of sulphuric acid, and calcined to a fairly grey ash. The residue in the platinum basin is boiled in water, and filtered. A few drops of carbonate of ammonia are added, the solution is evaporated to dryness and gently ignited at a low red-heat, and the contents of the basin are washed out into a flask and titrated with normal acid, calculating the results of the titration to potassium carbonate. As beet-sugar ash contains some 50 per cent. of potassium carbonate and 15–20 per cent. of sodium carbonate, the error incurred by this process is very small.

Unknown Organic Matter.—For ordinary commercial purposes, this is always determined by difference, i.e. by adding together crystallizable sugar, uncrystallizable sugar, ash, and moisture, and deducting the product from 100. It is obvious that this method affords no check upon the figures which have been obtained from the other processes, but it is practically essential in dealing with samples the analysis of which is required promptly, to use methods which are capable of rapid execution.

Results.—The results obtained by these analyses are always worked up in France, and practically in this country, to what is called the *rendement.* This figure is obtained in the case of beet-sugar by deducting the uncrystallizable sugar present, and 5 times the proportion of ash from the crystallizable sugar found. Thus supposing the crystallizable sugar was 90 per cent., the uncrystallizable sugar 1 per cent., and the ash 1 per cent., the *rendement* would be worked up by saying $90 - 1 = 89 - (1 \times 5) = 84$, and this would be, according to the view thus taken of it, the actual *rendement* or proportion of sugar which a refiner would be able to extract.

In the case of cane-sugar, only 3 times the ash is deducted, as, from the much smaller quantity of alkaline salts which these sugars contain, only about 3 times the weight of ash is rendered uncrystallizable instead of 5. It is often the case that with ordinary commercial sugars, the *rendement* thus obtained gives a very accurate estimate of the value of the sugar to the refiner, but there are certain cases in which the errors incurred are considerable.

Special Processes.—Having dealt with the ordinary and recognised commercial modes of sugar analysis, reference will now be made to those methods which are used as subsidiary processes in some cases of commercial work, and in other cases only for the purpose of special tests in refineries or sugar-*usines.*

Payen's process.—The alcohol process, which is often also called Payen's process, consists in washing the sample on a filter with alcohol of 88 per cent. strength, which has already been saturated with cane-sugar, and slightly acidified with acetic acid. The washing alcohol being already saturated with pure cane-sugar, cannot dissolve any more of that substance; but it is capable of dissolving uncrystallizable sugar and the salts occurring as impurities, while the acid which is present is sufficient in quantity to dissolve almost if not quite all the soluble matters not soluble in alcohol, and to decompose the sucrates. The test is carried out as follows. Three solutions are prepared, viz. (1) a mixture of absolute alcohol and ether, (2) 88 per cent. alcohol to which has been added 50 *cc.* of acetic acid per *litre,* and which has been saturated with pure crystallizable sugar (loaf-sugar answers perfectly well), (3) 95 per cent. alcohol also saturated in the same way with sugar.

The sample to be tested is weighed and transferred to a small tube, similar to a chloride of calcium tube, but preferably longer. Solution No. 1 is then passed on to the sugar in quantity equal to about the bulk of the sugar itself, so as not only to remove the water, but to precipitate any cane-sugar which may be in combination or solution in the water. If the raw sugar is too moist, it is desirable to dry it previously, so that it does not contain more than 4–5 per cent. of moisture. The chloride of calcium tube should be provided with a stopcock at the bottom, to allow the solvents to remain in contact with the sugar for a sufficient time.

After 10–15 minutes, the liquid may be run off by the stopcock at the bottom, and solution No. 2 added. The sample to be acted upon by this solution will be practically freed from water, and the diluted acetic acid solution will dissolve out any lime-salts which may be present, and so free the crystals of sugar from mineral impurities naturally existing in it. This solution is withdrawn in the same way as No. 1, and solution No. 3 is then poured on, a 2nd or 3rd portion of this solution being used if necessary until it ceases to take up anything more, and the sugar under treatment has reached its greatest whiteness of colour. After this, it is necessary to draw air through the tube containing the sugar, in order to remove the alcohol, and the residue of the sample is emptied from the tube into a tared capsule, dried and weighed, or if preferred, the crystals of sugar thus obtained may be dissolved in water made up to a definite volume, and polarized.

This process reads as a complicated one, and it is no doubt difficult of execution by those who are unused to it; but the opinion of some who have employed it is that the residue thus obtained (which is called crystallizable sugar) does really represent very closely the amount of crystallizable sugar which can be obtained by ordinary refining processes. The differences which occur in the execution of the analysis are mainly those due to alteration of temperature and possible changes in the strength of the solutions of sugar. A rapid fall in temperature in the laboratory during the process of washing will render the results incorrect, owing to the deposition of sugar on the surface of the crystals of the sample being washed.

Fermentation Process.—It has been proposed, and to some extent practically carried out, to determine the proportion of cane-sugar in the solution by means of the estimation of (1) the proportion of alcohol formed by fermentation, and (2) the amount of carbonic acid evolved during fermentation.

(1) A solution of cane-sugar when fermented yields 51–51·2 parts by weight of alcohol. The process is carried out by placing a dilute solution of the sugar to be tested, mixed with a small proportion of yeast (4–5 per cent.) in a flask, keeping it at a temperature of 22°–25° (71½°–77° F.) until the fermentation has ceased, which will be in 3–4 days. The solution is afterwards distilled, and the amount of alcohol is determined in the distillate in the usual way. The calculation from the proportion of alcohol found to cane-sugar is of course easy, although not always accurate, because secondary fermentation attended with the formation of lactic acid and other bodies may take place.

(2) The sugar solution is fermented in a similar way, but in a flask closed except through one outlet, by which the evolved gases are allowed to escape into a suitable absorption tube or tubes, the first of which is filled with chloride of calcium or sulphuric acid, so as to absorb the moisture, and the second with a weighed solution of caustic alkali, to absorb the carbonic acid. It will of course be necessary in this case to draw, by means of an aspirator or other suitable appliance, a considerable amount of air through the apparatus after the conclusion of the fermentation, in order to remove the last traces of carbonic acid. Uncrystallizable sugar will, according to this method of analysis, yield both alcohol and carbonic acid, and the carbonic acid is determined by the gain in weight of the caustic alkali due to absorption of carbonic acid.

Fehling's method.—It is well known that acids have the property of converting cane-sugar into invert sugar in definite proportion. It is thus possible to heat a solution of cane-sugar with a proportion of acid, and after the inversion of the sugar, to determine the total proportion of invert sugar present by means of Fehling's solution; but this method has proved very inaccurate in practice.

Inversion.—It not unfrequently happens that commercial samples of sugar contain substances which have an optical rotatory effect on the polariscope, and in this case it is necessary to employ the process of inversion. Cane-sugar is the only sugar which is capable of inversion by acids. Solutions of cane-sugar left in contact with air, especially when those solutions are diluted, do invert, and when acid is present they invert much more rapidly: the rate of inversion seems to be dependent partly on the time, partly on the strength, and partly on the amount of acid used, but for practical analytical work a definite process is carried out which results in the transformation of the whole of the cane-sugar into invert sugar in a very short time.

This process is as follows. 50–100 *cc.* of the clarified sugar solution is diluted with $\frac{1}{10}$ its volume of concentrated hydrochloric acid, and after admixture, the acidified solution is gradually heated to 68° (154° F.), the heating being so arranged as to occupy about 15–20 minutes. By this time, the cane-sugar present is wholly converted into invert sugar, and the solution is capable of being polarized, so that two readings of the polariscope before and after inversion may be compared.

If both readings are on either the right or left of the scale, the smaller is deducted from the greater, to give the angle of rotation sought; if, however, after inversion, the right-handed rotation is changed to left, so that the two readings are right and left of zero, their sums are taken, and the percentage of cane-sugar is found either by Clerget's tables, or by the following rule:—

A 16·35 per cent. solution of pure sugar, reading 100° to the right, will, when inverted, read 44° to the left, at 0° (32° F.); this action is expressed by

$$T = 144 - \tfrac{1}{2}T.$$

Therefore if S represents the sum or difference of rotations, T the temperature, and R the percentage of crystallizable sugar sought;

$$\text{then } 144 - \tfrac{1}{2}T : 100 :: S : R.$$

In this case, it is essential to note the temperature of the liquid when the second reading is taken, because invert sugar changes rapidly in its angle of polarization, according to its temperature.

This is not the case with cane-sugar.

The following are Clerget's tables referred to:—

Clerget's Table for the Analyses of Saccharine Substances.

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B.
																											gram.
1·4	1·4	1·4	1·4	1·4	1·4	1·4	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1·3	1	1·64
2·8	2·8	2·8	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·7	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2·6	2	3·29
4·2	4·1	4·1	4·1	4·1	4·1	4·1	4·1	4·0	4·0	4·0	4·0	4·0	4·0	4·0	3·9	3·9	3·9	3·9	3·9	3·9	3·8	3·8	3·8	3·8	3·8	3	4·94
5·6	5·5	5·5	5·5	5·5	5·5	5·4	5·4	5·4	5·4	5·4	5·3	5·3	5·3	5·3	5·3	5·2	5·2	5·2	5·2	5·2	5·1	5·1	5·1	5·1	5·1	4	6·58
6·9	6·9	6·9	6·9	6·8	6·8	6·8	6·8	6·7	6·7	6·7	6·7	6·6	6·6	6·6	6·6	6·5	6·5	6·5	6·5	6·4	6·4	6·4	6·4	6·3	6·3	5	8·23
8·3	8·3	8·3	8·2	8·2	8·2	8·2	8·1	8·1	8·1	8·0	8·0	8·0	7·9	7·9	7·9	7·9	7·8	7·8	7·8	7·7	7·7	7·7	7·7	7·6	7·6	6	9·88
9·7	9·7	9·7	9·6	9·6	9·5	9·5	9·5	9·4	9·4	9·4	9·3	9·3	9·3	9·2	9·2	9·2	9·1	9·1	9·1	9·0	9·0	9·0	8·9	8·9	8·8	7	11·52
11·1	11·1	11·0	11·0	11·0	10·9	10·9	10·8	10·8	10·8	10·7	10·7	10·6	10·6	10·6	10·5	10·5	10·4	10·4	10·4	10·3	10·3	10·2	10·2	10·2	10·1	8	13·17
12·5	12·5	12·4	12·4	12·3	12·3	12·2	12·2	12·1	12·1	12·1	12·0	12·0	11·9	11·9	11·8	11·8	11·7	11·7	11·6	11·6	11·6	11·5	11·5	11·4	11·4	9	14·82
13·9	13·8	13·8	13·7	13·7	13·6	13·6	13·5	13·5	13·4	13·4	13·3	13·3	13·2	13·2	13·1	13·1	13·0	13·0	12·9	12·9	12·8	12·8	12·7	12·7	12·6	10	16·47
15·3	15·2	15·2	15·1	15·1	15·0	15·0	14·9	14·8	14·8	14·7	14·7	14·6	14·6	14·5	14·5	14·4	14·3	14·3	14·2	14·2	14·1	14·1	14·0	14·0	13·9	11	18·11
16·7	16·6	16·6	16·5	16·4	16·4	16·3	16·3	16·2	16·1	16·1	16·0	16·0	15·9	15·8	15·8	15·7	15·7	15·6	15·5	15·5	15·4	15·4	15·3	15·2	15·2	12	19·76
18·1	18·0	17·9	17·9	17·8	17·7	17·7	17·6	17·5	17·5	17·4	17·3	17·3	17·2	17·2	17·1	17·0	17·0	16·9	16·8	16·8	16·7	16·6	16·6	16·5	16·4	13	21·41
19·5	19·4	19·3	19·2	19·2	19·1	19·0	19·0	18·9	18·8	18·8	18·7	18·6	18·5	18·5	18·4	18·3	18·3	18·2	18·1	18·1	18·0	17·9	17·8	17·8	17·7	14	23·05
20·8	20·8	20·7	20·6	20·5	20·5	20·4	20·3	20·2	20·2	20·1	20·0	19·9	19·9	19·8	19·7	19·6	19·6	19·5	19·4	19·3	19·3	19·2	19·1	19·0	19·0	15	24·70
22·2	22·2	22·1	22·0	21·9	21·8	21·8	21·7	21·6	21·5	21·4	21·4	21·3	21·2	21·1	21·0	21·0	20·9	20·8	20·7	20·6	20·6	20·5	20·4	20·3	20·2	16	26·35
23·6	23·5	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	22·7	22·6	22·5	22·4	22·3	22·3	22·2	22·1	22·0	21·9	21·8	21·7	21·7	21·6	21·5	17	28·00
25·0	24·9	24·8	24·7	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	23·9	23·8	23·8	23·7	23·6	23·5	23·4	23·3	23·2	23·1	23·0	22·9	22·9	22·8	18	29·64
26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·5	25·4	25·3	25·2	25·1	25·0	24·9	24·8	24·7	24·6	24·5	24·4	24·3	24·2	24·1	24·0	19	31·29
27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26·9	26·8	26·7	26·6	26·5	26·4	26·3	26·2	26·1	26·0	25·9	25·8	25·7	25·6	25·5	25·4	25·3	20	32·94
29·2	29·1	29·0	28·9	28·8	28·7	28·6	28·4	28·3	28·2	28·1	28·0	27·9	27·8	27·7	27·6	27·5	27·4	27·3	27·2	27·1	27·0	26·9	26·8	26·7	26·6	21	34·58
30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·6	29·5	29·4	29·3	29·1	29·0	28·9	28·8	28·7	28·6	28·5	28·4	28·3	28·2	28·0	27·9	27·8	22	36·23
32·0	31·8	31·7	31·6	31·5	31·4	31·3	31·2	31·0	30·9	30·8	30·7	30·6	30·5	30·4	30·2	30·1	30·0	29·9	29·8	29·7	29·5	29·5	29·3	29·2	29·1	23	37·88
33·4	33·2	33·1	33·0	32·9	32·8	32·6	32·5	32·4	32·3	32·2	32·0	31·9	31·8	31·7	31·6	31·4	31·3	31·2	31·1	30·9	30·8	30·7	30·6	30·5	30·4	24	39·53
34·7	34·6	34·5	34·4	34·2	34·1	34·0	33·9	33·7	33·6	33·5	33·4	33·2	33·1	33·0	32·9	32·7	32·6	32·5	32·4	32·2	32·1	32·0	31·9	31·7	31·6	25	41·17
36·1	36·0	35·9	35·7	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·2	34·1	33·9	33·8	33·7	33·5	33·4	33·3	33·1	33·0	32·9	26	42·82
37·5	37·4	37·3	37·1	37·0	36·8	36·7	36·6	36·4	36·3	36·2	36·1	35·9	35·8	35·6	35·5	35·4	35·2	35·1	35·0	34·8	34·7	34·6	34·4	34·3	34·1	27	44·47
38·9	38·8	38·6	38·5	38·4	38·2	38·1	37·9	37·8	37·7	37·5	37·4	37·2	37·1	37·0	36·8	36·7	36·5	36·4	36·3	36·1	36·0	35·8	35·7	35·6	35·4	28	46·11
40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·9	38·7	38·6	38·4	38·3	38·1	38·0	37·8	37·7	37·5	37·4	37·3	37·1	37·0	36·8	36·7	29	47·76
41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·5	40·3	40·2	40·0	39·9	39·7	39·6	39·4	39·3	39·1	39·0	38·8	38·7	38·5	38·4	38·2	38·1	37·9	30	49·41
43·1	42·9	42·8	42·6	42·5	42·3	42·2	42·0	41·8	41·7	41·5	41·4	41·2	41·1	40·9	40·8	40·6	40·4	40·3	40·1	39·9	39·8	39·7	39·5	39·4	39·2	31	51·06
44·5	44·3	44·2	44·0	43·8	43·7	43·5	43·4	43·2	43·0	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·8	41·6	41·4	41·3	41·1	41·0	40·8	40·6	40·5	32	52·70
45·9	45·7	45·5	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·6	43·4	43·2	43·1	42·9	42·7	42·6	42·4	42·2	42·1	41·9	41·7	33	54·35

Clerget's Table for the Analyses of Saccharine Substances—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B. gram.
47·3	47·1	46·9	46·7	46·6	46·4	46·2	46·1	45·9	45·7	45·6	45·4	45·2	45·0	44·9	44·7	44·5	44·4	44·2	44·0	43·9	43·7	43·5	43·3	43·2	43·0	34	56·00
48·6	48·5	48·3	48·1	47·9	47·8	47·6	47·4	47·2	47·1	46·9	46·7	46·5	46·4	46·2	46·0	45·8	45·7	45·5	45·3	45·1	45·0	44·8	44·6	44·4	44·3	35	57·64
50·0	49·9	49·7	49·5	49·3	49·1	49·0	48·8	48·6	48·4	48·2	48·1	47·9	47·7	47·5	47·3	47·2	47·0	46·8	46·6	46·4	46·3	46·1	45·9	45·7	45·5	36	59·29
51·4	51·2	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·8	49·6	49·4	49·2	49·0	48·8	48·6	48·5	48·3	48·1	47·9	47·7	47·5	47·4	47·2	47·0	46·8	37	60·94
52·8	52·6	52·4	52·2	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·2	50·0	49·8	49·6	49·4	49·2	49·0	48·8	48·7	48·4	48·3	48·1	38	62·58
54·2	54·0	53·8	53·6	53·4	53·2	53·0	52·8	52·6	52·4	52·3	52·1	51·9	51·7	51·5	51·3	51·1	50·9	50·7	50·5	50·3	50·1	49·9	49·7	49·5	49·3	39	64·23
55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·6	53·4	53·2	53·0	52·8	52·6	52·4	52·2	52·0	51·8	51·6	51·4	51·2	51·0	50·8	50·6	40	65·88
57·0	56·8	56·6	56·4	56·2	56·0	55·8	55·5	55·3	55·1	54·9	54·7	54·5	54·3	54·1	53·9	53·7	53·5	53·3	53·1	52·9	52·7	52·5	52·3	52·1	51·9	41	67·53
58·4	58·2	58·0	57·7	57·5	57·3	57·1	56·9	56·7	56·5	56·3	56·1	55·9	55·6	55·4	55·2	55·0	54·8	54·6	54·4	54·2	54·0	53·8	53·5	53·3	53·1	42	69·17
59·8	59·5	59·3	59·1	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	55·5	55·2	55·0	54·8	54·6	54·4	43	70·82
61·2	60·9	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	59·0	58·7	58·5	58·3	58·1	57·9	57·6	57·4	57·2	57·0	56·8	56·5	56·3	56·1	55·9	55·7	44	72·47
62·5	62·3	62·1	61·9	61·6	61·4	61·2	61·0	60·7	60·5	60·3	60·1	59·8	59·6	59·4	59·2	58·9	58·7	58·5	58·3	58·0	57·8	57·6	57·4	57·1	56·9	45	74·11
63·9	63·7	63·5	63·2	63·0	62·8	62·6	62·3	62·1	61·9	61·6	61·4	61·2	60·9	60·7	60·5	60·3	60·0	59·8	59·6	59·3	59·1	58·9	58·6	58·4	58·2	46	75·76
65·3	65·1	64·9	64·6	64·4	64·1	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·3	62·0	61·8	61·6	61·3	61·1	60·9	60·6	60·4	60·2	59·9	59·7	59·4	47	77·41
66·7	66·5	66·2	66·0	65·8	65·5	65·3	65·0	64·8	64·6	64·3	64·1	63·8	63·6	63·4	63·1	62·9	62·6	62·4	62·2	61·9	61·7	61·4	61·2	61·0	60·7	48	79·06
68·1	67·9	67·6	67·4	67·1	66·9	66·6	66·4	66·1	65·9	65·7	65·4	65·2	64·9	64·7	64·4	64·2	63·9	63·7	63·4	63·2	63·0	62·7	62·5	62·2	62·0	49	80·70
69·5	69·2	69·0	68·7	68·5	68·2	68·0	67·7	67·5	67·2	67·0	66·7	66·5	66·2	66·0	65·7	65·5	65·2	65·0	64·7	64·5	64·2	64·0	63·7	63·5	63·2	50	82·35
70·9	70·6	70·4	70·1	69·9	69·6	69·4	69·1	68·8	68·6	68·3	68·1	67·8	67·6	67·3	67·1	66·8	66·5	66·3	66·0	65·8	65·5	65·3	65·0	64·8	64·5	51	84·00
72·3	72·0	71·8	71·5	71·2	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·9	67·6	67·3	67·1	66·8	66·6	66·3	66·0	65·8	52	85·64
73·7	73·4	73·1	72·9	72·6	72·3	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	70·0	69·7	69·4	69·2	68·9	68·6	68·4	68·1	67·8	67·6	67·3	67·0	53	87·29
75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·2	72·9	72·6	72·4	72·1	71·8	71·5	71·3	71·0	70·7	70·5	70·2	69·9	69·7	69·4	69·1	68·8	68·6	68·3	54	88·94
76·4	76·2	75·9	75·6	75·3	75·1	74·8	74·5	74·2	74·0	73·7	73·4	73·1	72·9	72·6	72·3	72·0	71·8	71·5	71·2	70·9	70·7	70·4	70·1	69·8	69·6	55	90·59
77·8	77·6	77·3	77·0	76·7	76·4	76·2	75·9	75·6	75·3	75·0	74·8	74·5	74·2	73·9	73·6	73·4	73·1	72·8	72·5	72·2	72·0	71·7	71·4	71·1	70·8	56	92·23
79·2	79·0	78·7	78·4	78·1	77·8	77·5	77·2	76·9	76·7	76·4	76·1	75·8	75·5	75·2	74·9	74·7	74·4	74·1	73·8	73·5	73·2	73·0	72·7	72·4	72·1	57	93·88
80·6	80·3	80·0	79·7	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·6	76·3	76·0	75·7	75·4	75·1	74·8	74·5	74·2	73·9	73·7	73·4	58	95·53
82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·1	78·8	78·5	78·2	77·9	77·6	77·3	77·0	76·7	76·4	76·1	75·8	75·5	75·2	74·9	74·6	59	97·17
83·4	83·1	82·8	82·5	82·2	81·9	81·6	81·3	81·0	80·7	80·4	80·1	79·8	79·5	79·2	78·9	78·6	78·3	78·0	77·7	77·4	77·1	76·8	76·5	76·2	75·9	60	98·82
84·8	84·5	84·2	83·9	83·6	83·3	83·0	82·6	82·3	82·0	81·7	81·4	81·1	80·8	80·5	80·2	79·9	79·6	79·3	79·0	78·7	78·4	78·1	77·8	77·5	77·2	61	100·47
86·2	85·9	85·6	85·2	84·9	84·6	84·3	84·0	83·7	83·4	83·1	82·8	82·5	82·1	81·8	81·5	81·2	80·9	80·6	80·3	80·0	79·7	79·4	79·0	78·7	78·4	62	102·12
87·6	87·2	86·9	86·5	86·3	86·0	85·7	85·4	85·0	84·7	84·4	84·1	83·8	83·5	83·2	82·8	82·5	82·2	81·9	81·6	81·3	80·9	80·6	80·3	80·0	79·7	63	103·76
89·0	88·6	88·3	88·0	87·7	87·4	87·0	86·7	86·4	86·1	85·8	85·4	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·6	82·2	81·9	81·6	81·3	81·0	64	105·41
90·3	90·0	89·7	89·4	89·0	88·7	88·4	88·1	87·7	87·4	87·1	86·8	86·4	86·1	85·8	85·5	85·1	84·8	84·5	84·2	83·8	83·5	83·2	82·9	82·5	82·2	65	107·06
91·7	91·4	91·1	90·7	90·4	90·1	89·8	89·4	89·1	88·8	88·4	88·1	87·8	87·4	87·1	86·8	86·5	86·1	85·8	85·5	85·1	84·8	84·5	84·1	83·8	83·5	66	108·70

CLERGET'S TABLE FOR THE ANALYSES OF SACCHARINE SUBSTANCES—*continued.*

Sums and Differences of the Deviations, Direct and Inverse, taken at the Temperatures (Cent.)																										Per ct. sought.	
10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	By wt. A.	By vol. B.
																											gram.
93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·8	90·4	90·1	89·8	89·4	89·1	88·8	88·4	88·1	87·8	87·4	87·1	86·8	86·4	86·1	85·8	85·4	85·1	84·8	67	110·35
94·5	94·2	93·8	93·5	93·2	92·8	92·5	92·1	91·8	91·5	91·1	90·8	90·4	90·1	89·8	89·4	89·1	88·7	88·4	88·1	87·7	87·4	87·0	86·7	86·4	86·0	68	112·00
95·9	95·6	95·2	94·9	94·5	94·1	93·8	93·5	93·1	92·8	92·5	92·1	91·8	91·4	91·1	90·7	90·4	90·0	89·7	89·3	89·0	88·7	88·3	88·0	87·6	87·3	69	113·64
97·3	96·9	96·6	96·2	95·9	95·5	95·2	94·8	94·5	94·1	93·8	93·4	93·1	92·7	92·4	92·0	91·7	91·3	91·0	90·6	90·3	89·9	89·6	89·2	88·9	88·5	70	115·29
98·7	98·3	98·0	97·6	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·8	94·4	94·1	93·7	93·4	93·0	92·6	92·3	91·9	91·6	91·2	90·9	90·5	90·2	89·8	71	116·94
100·1	99·7	99·4	99·0	98·6	98·3	97·9	97·6	97·2	96·8	96·5	96·1	95·8	95·4	95·0	94·7	94·3	94·0	93·6	93·2	92·9	92·5	92·2	91·8	91·4	91·1	72	118·59
101·5	101·1	100·7	100·4	100·0	99·6	99·3	98·9	98·5	98·2	97·8	97·4	97·1	96·7	96·4	96·0	95·6	95·3	94·9	94·5	94·2	93·8	93·4	93·1	92·7	92·3	73	120·23
102·9	102·5	102·1	101·7	101·4	101·0	100·6	100·3	99·9	99·5	99·2	98·8	98·4	98·0	97·7	97·3	96·9	96·6	96·2	95·8	95·5	95·1	94·7	94·3	94·0	93·6	74	121·88
104·2	103·9	103·5	103·1	102·7	102·4	102·0	101·6	101·2	100·9	100·5	100·1	99·7	99·4	99·0	98·6	98·2	97·9	97·5	97·1	96·7	96·4	96·0	95·6	95·2	94·9	75	123·53
105·6	105·3	104·9	104·5	104·1	103·7	103·4	103·0	102·6	102·2	101·8	101·5	101·1	100·7	100·3	99·9	99·6	99·2	98·8	98·4	98·0	97·7	97·3	96·9	96·5	96·1	76	125·17
107·0	106·6	106·3	105·9	105·5	105·1	104·7	104·3	103·9	103·6	103·2	102·8	102·4	102·0	101·6	101·2	100·9	100·5	100·1	99·7	99·3	98·9	98·6	98·2	97·8	97·4	77	126·82
108·4	108·0	107·6	107·2	106·9	106·5	106·1	105·7	105·3	104·9	104·5	104·1	103·7	103·3	103·0	102·6	102·2	101·8	101·4	101·0	100·6	100·2	99·8	99·4	99·1	98·7	78	128·47
109·8	109·4	109·0	108·6	108·2	107·8	107·4	107·0	106·6	106·2	105·9	105·5	105·1	104·7	104·3	103·9	103·5	103·1	102·7	102·3	101·9	101·5	101·1	100·7	100·3	99·9	79	130·12
111·2	110·8	110·4	110·0	109·6	109·2	108·8	108·4	108·0	107·6	107·2	106·8	106·4	106·0	105·6	105·2	104·8	104·4	104·0	103·6	103·2	102·8	102·4	102·0	101·6	101·2	80	131·76
112·6	112·2	111·8	111·4	111·0	110·6	110·2	109·7	109·3	108·9	108·5	108·1	107·7	107·3	106·9	106·5	106·1	105·7	105·3	104·9	104·6	104·1	103·7	103·2	102·9	102·5	81	133·41
114·0	113·6	113·2	112·7	112·3	111·9	111·5	111·1	110·7	110·3	109·9	109·5	109·1	108·6	108·2	107·8	107·4	107·0	106·6	106·2	105·9	105·4	105·0	104·5	104·1	103·7	82	135·06
115·4	114·9	114·5	114·1	113·7	113·3	112·9	112·5	112·0	111·6	111·2	110·8	110·4	110·0	109·6	109·1	108·7	108·3	107·9	107·5	107·2	106·6	106·2	105·8	105·4	105·0	83	136·70
116·8	116·3	115·9	115·5	115·1	114·7	114·2	113·8	113·4	113·0	112·6	112·1	111·7	111·3	110·9	110·5	110·0	109·6	109·2	108·8	108·5	107·9	107·5	107·1	106·7	106·3	84	138·35
118·1	117·7	117·3	116·9	116·4	116·0	115·6	115·2	114·7	114·3	113·9	113·5	113·0	112·6	112·2	111·8	111·3	110·9	110·5	110·1	109·7	109·2	108·8	108·4	107·9	107·5	85	140·00
119·5	119·1	118·7	118·2	117·8	117·4	117·0	116·5	116·1	115·7	115·2	114·8	114·4	113·9	113·5	113·1	112·7	112·2	111·8	111·4	111·0	110·5	110·1	109·6	109·2	108·8	86	141·65
120·9	120·5	120·1	119·6	119·2	118·7	118·3	117·9	117·4	117·0	116·6	116·1	115·7	115·3	114·8	114·4	114·0	113·5	113·1	112·7	112·3	111·8	111·4	110·9	110·5	110·0	87	143·29
122·3	121·9	121·4	121·0	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·2	115·7	115·3	114·8	114·4	114·0	113·6	113·1	112·6	112·2	111·8	111·3	88	144·94
123·7	123·2	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·8	118·4	117·9	117·5	117·0	116·6	116·1	115·7	115·2	114·9	114·4	113·9	113·5	113·0	112·6	89	146·59
125·1	124·6	124·2	123·7	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·8	118·3	117·9	117·4	117·0	116·5	116·2	115·6	115·2	114·7	114·3	113·9	90	148·23
126·5	126·0	125·6	125·1	124·7	124·2	123·8	123·3	122·8	122·4	121·9	121·5	121·0	120·6	120·1	119·7	119·2	118·7	118·3	117·8	117·5	116·9	116·5	116·0	115·6	115·1	91	149·88
127·9	127·4	127·0	126·5	126·0	125·6	125·1	124·7	124·2	123·7	123·3	122·8	122·4	121·9	121·4	121·0	120·5	120·1	119·6	119·1	118·8	118·2	117·8	117·3	116·8	116·4	92	151·53
129·3	128·8	128·3	127·9	127·4	126·9	126·5	126·0	125·5	125·1	124·6	124·1	123·7	123·2	122·8	122·3	121·8	121·4	120·9	120·4	120·1	119·5	119·0	118·6	118·1	117·6	93	153·18
130·7	130·2	129·7	129·2	128·8	128·3	127·8	127·4	126·9	126·4	126·0	125·5	125·0	124·5	124·1	123·6	123·1	122·7	122·2	121·7	121·4	120·8	120·3	119·8	119·4	118·9	94	154·82
132·0	131·6	131·1	130·6	130·1	129·7	129·2	128·7	128·2	127·8	127·3	126·8	126·3	125·9	125·4	124·9	124·4	124·0	123·5	123·0	122·6	122·1	121·6	121·1	120·6	120·2	95	156·47
133·4	133·0	132·5	132·0	131·5	131·0	130·6	130·1	129·6	129·1	128·6	128·2	127·7	127·2	126·7	126·2	125·8	125·3	124·8	124·3	123·9	123·4	122·9	122·4	121·9	121·4	96	158·12
134·8	134·3	133·9	133·4	132·9	132·4	131·9	131·4	130·9	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·1	126·6	126·1	125·6	125·2	124·6	124·2	123·7	123·2	122·7	97	159·76
136·2	135·7	135·2	134·7	134·3	133·8	133·3	132·8	132·3	131·8	131·3	130·8	130·3	129·8	129·4	128·9	128·4	127·9	127·4	126·9	126·5	125·9	125·4	124·9	124·5	124·0	98	161·41
137·6	137·1	136·6	136·1	135·6	135·1	134·6	134·1	133·6	133·1	132·7	132·2	131·7	131·2	130·7	130·2	129·7	129·2	128·7	128·2	127·8	127·2	126·7	126·2	125·7	125·2	99	163·06
139·0	138·5	138·0	137·5	137·0	136·5	136·0	135·5	135·0	134·5	134·0	133·5	133·0	132·5	132·0	131·5	131·0	130·5	130·0	129·5	129·0	128·5	128·0	127·5	127·0	126·5	100	164·71

Cane- and Beet-Juice.—In the ordinary average-work of the factory, the percentage of sugar present in the juice being treated is determined mainly by means of the saccharometer, according to the following tables :—

TABLE SHOWING THE RELATION OF PERCENTAGES, SPECIFIC GRAVITIES, AND DEGREES BAUMÉ IN CANE-SUGAR SOLUTIONS.

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
0·0	1·0000	0·0	6·2	1·0245	3·4	12·4	1·0502	6·9	18·6	1·0770	10·3
·1	1·0003	0·06	·3	1·0249	3·5	·5	1·0506	6·9	·7	1·0775	10·35
·2	1·0007	0·11	·4	1·0253	3·6	·6	1·0510	7·0	·8	1·0779	10·4
·3	1·0011	0·17	·5	1·0257	3·6	·7	1·0514	7·05	·9	1·0783	10·5
·4	1·0015	0·22	·6	1·0261	3·7	·8	1·0519	7·1	19·0	1·0788	10·5
·5	1·0019	0·28	·7	1·0265	3·7	·9	1·0523	7·2	·1	1·0792	10·6
·6	1·0023	0·33	·8	1·0269	3·8	13·0	1·0527	7·2	·2	1·0797	10·6
·7	1·0027	0·39	·9	1·0273	3·8	·1	1·0531	7·3	·3	1·0801	10·7
·8	1·0031	0·44	7·0	1·0277	3·9	·2	1·0536	7·3	·4	1·0806	10·7
·9	1·0034	0·5	·1	1·0281	3·9	·3	1·0540	7·4	·5	1·0810	10·8
1·0	1·0038	0·55	·2	1·0286	4·0	·4	1·0544	7·4	·6	1·0815	10·85
·1	1·0042	0·6	·3	1·0290	4·1	·5	1·0548	7·5	·7	1·0819	10·9
·2	1·0046	0·7	·4	1·0294	4·1	·6	1·0553	7·5	·8	1·0824	11·0
·3	1·0050	0·7	·5	1·0298	4·2	·7	1·0557	7·6	·9	1·0828	11·0
·4	1·0054	0·8	·6	1·0302	4·2	·8	1·0561	7·65	20·0	1·0832	11·1
·5	1·0058	0·8	·7	1·0306	4·3	·9	1·0566	7·7	·1	1·0837	11·1
·6	1·0062	0·9	·8	1·0310	4·3	14·0	1·0570	7·8	·2	1·0841	11·2
·7	1·0066	0·9	·9	1·0314	4·4	·1	1·0574	7·8	·3	1·0846	11·2
·8	1·0070	1·0	8·0	1·0318	4·4	·2	1·0578	7·9	·4	1·0850	11·3
·9	1·0074	1·05	·1	1·0322	4·5	·3	1·0583	7·9	·5	1·0855	11·3
2·0	1·0077	1·1	·2	1·0327	4·55	·4	1·0587	8·0	·6	1·0859	11·4
·1	1·0081	1·2	·3	1·0331	4·6	·5	1·0591	8·0	·7	1·0864	11·45
·2	1·0085	1·2	·4	1·0335	4·7	·6	1·0596	8·1	·8	1·0868	11·5
·3	1·0089	1·3	·5	1·0339	4·7	·7	1·0600	8·15	·9	1·0873	11·6
·4	1·0093	1·3	·6	1·0343	4·8	·8	1·0604	8·2	21·0	1·0877	11·6
·5	1·0097	1·4	·7	1·0347	4·8	·9	1·0609	8·3	·1	1·0882	11·7
·6	1·0101	1·4	·8	1·0351	4·9	15·0	1·0613	8·3	·2	1·0886	11·7
·7	1·0105	1·5	·9	1·0355	4·9	·1	1·0617	8·4	·3	1·0891	11·8
·8	1·0109	1·55	9·0	1·0359	5·0	·2	1·0621	8·4	·4	1·0895	11·8
·9	1·0113	1·6	·1	1·0364	5·05	·3	1·0626	8·5	·5	1·0900	11·9
3·0	1·0117	1·7	·2	1·0368	5·1	·4	1·0630	8·5	·6	1·0904	11·95
·1	1·0121	1·7	·3	1·0372	5·2	·5	1·0634	8·6	·7	1·0909	12·0
·2	1·0125	1·8	·4	1·0376	5·2	·6	1·0639	8·65	·8	1·0914	12·05
·3	1·0129	1·8	·5	1·0380	5·3	·7	1·0643	8·7	·9	1·0918	12·1
·4	1·0133	1·9	·6	1·0384	5·3	·8	1·0647	8·8	22·0	1·0923	12·2
·5	1·0137	1·9	·7	1·0388	5·4	·9	1·0652	8·8	·1	1·0927	12·2
·6	1·0141	2·0	·8	1·0393	5·4	16·0	1·0656	8·9	·2	1·0932	12·3
·7	1·0145	2·0	·9	1·0397	5·5	·1	1·0660	8·9	·3	1·0936	12·3
·8	1·0149	2·1	10·0	1·0401	5·55	·2	1·0665	9·0	·4	1·0941	12·4
·9	1·0153	2·2	·1	1·0405	5·6	·3	1·0669	9·0	·5	1·0945	12·4
4·0	1·0157	2·2	·2	1·0409	5·7	·4	1·0674	9·1	·6	1·0950	12·5
·1	1·0161	2·3	·3	1·0413	5·7	·5	1·0678	9·1	·7	1·0954	12·55
·2	1·0165	2·3	·4	1·0418	5·8	·6	1·0682	9·2	·8	1·0959	12·6
·3	1·0169	2·4	·5	1·0422	5·8	·7	1·0687	9·25	·9	1·0964	12·7
·4	1·0173	2·4	·6	1·0426	5·9	·8	1·0691	9·3	23·0	1·0968	12·7
·5	1·0177	2·5	·7	1·0430	5·9	·9	1·0695	9·4	·1	1·0973	12·8
·6	1·0181	2·6	·8	1·0434	6·0	17·0	1·0700	9·4	·2	1·0977	12·8
·7	1·0185	2·6	·9	1·0439	6·05	·1	1·0704	9·5	·3	1·0982	12·9
·8	1·0189	2·7	11·0	1·0443	6·1	·2	1·0709	9·5	·4	1·0986	12·9
·9	1·0193	2·7	·1	1·0447	6·2	·3	1·0713	9·6	·5	1·0991	13·0
5·0	1·0197	2·8	·2	1·0451	6·2	·4	1·0717	9·6	·6	1·0996	13·0
·1	1·0201	2·8	·3	1·0455	6·3	·5	1·0722	9·7	·7	1·1000	13·1
·2	1·0205	2·9	·4	1·0459	6·3	·6	1·0726	9·75	·8	1·1005	13·15
·3	1·0209	2·9	·5	1·0464	6·4	·7	1·0730	9·8	·9	1·1009	13·2
·4	1·0213	3·0	·6	1·0468	6·4	·8	1·0735	9·9	24·0	1·1014	13·3
·5	1·0217	3·0	·7	1·0472	6·5	·9	1·0739	9·9	·1	1·1019	13·3
·6	1·0221	3·1	·8	1·0476	6·55	18·0	1·0744	10·0	·2	1·1023	13·4
·7	1·0225	3·2	·9	1·0481	6·6	·1	1·0748	10·0	·3	1·1028	13·4
·8	1·0229	3·2	12·0	1·0485	6·7	·2	1·0753	10·1	·4	1·1032	13·5
·9	1·0233	3·3	·1	1·0489	6·7	·3	1·0757	10·1	·5	1·1037	13·5
6·0	1·0237	3·3	·2	1·0493	6·8	·4	1·0761	10·2	·6	1·1042	13·6
·1	1·0241	3·4	·3	1·0497	6·8	·5	1·0766	10·2	·7	1·1046	13·6

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
24·8	1·1051	13·7	31·6	1·1374	17·4	38·4	1·1712	21·05	45·2	1·2067	24·7
·9	1·1056	13·75	·7	1·1378	17·4	·5	1·1717	21·1	·3	1·2072	24·7
25·0	1·1060	13·8	·8	1·1383	17·5	·6	1·1722	21·15	·4	1·2077	24·8
·1	1·1065	13·9	·9	1·1388	17·55	·7	1·1727	21·2	·5	1·2083	24·8
·2	1·1070	13·9	32·0	1·1393	17·6	·8	1·1732	21·3	·6	1·2088	24·9
·3	1·1074	14·0	·1	1·1398	17·7	·9	1·1737	21·3	·7	1·2093	24·9
·4	1·1079	14·0	·2	1·1403	17·7	39·0	1·1743	21·4	·8	1·2099	25·0
·5	1·1083	14·1	·3	1·1408	17·8	·1	1·1748	21·4	·9	1·2104	25·0
·6	1·1088	14·1	·4	1·1412	17·8	·2	1·1753	21·5	46·0	1·2110	25·1
·7	1·1093	14·2	·5	1·1417	17·9	·3	1·1758	21·5	·1	1·2115	25·1
·8	1·1097	14·2	·6	1·1422	17·9	·4	1·1763	21·6	·2	1·2120	25·2
·9	1·1102	14·3	·7	1·1427	18·0	·5	1·1768	21·6	·3	1·2126	25·2
26·0	1·1107	14·35	·8	1·1432	18·0	·6	1·1773	21·7	·4	1·2131	25·3
·1	1·1111	14·4	·9	1·1437	18·1	·7	1·1778	21·7	·5	1·2136	25·35
·2	1·1116	14·5	33·0	1·1442	18·15	·8	1·1784	21·8	·6	1·2142	25·4
·3	1·1121	14·5	·1	1·1447	18·2	·9	1·1789	21·85	·7	1·2147	25·45
·4	1·1125	14·6	·2	1·1452	18·25	40·0	1·1794	21·9	·8	1·2153	25·5
·5	1·1130	14·6	·3	1·1457	18·3	·1	1·1799	22·0	·9	1·2158	25·6
·6	1·1135	14·7	·4	1·1462	18·4	·2	1·1804	22·0	47·0	1·2163	25·6
·7	1·1140	14·7	·5	1·1466	18·4	·3	1·1809	22·1	·1	1·2169	25·7
·8	1·1144	14·8	·6	1·1471	18·5	·4	1·1815	22·1	·2	1·2174	25·7
·9	1·1149	14·8	·7	1·1476	18·5	·5	1·1820	22·2	·3	1·2180	25·8
27·0	1·1154	14·9	·8	1·1481	18·6	·6	1·1825	22·2	·4	1·2185	25·8
·1	1·1158	14·9	·9	1·1486	18·6	·7	1·1830	22·3	·5	1·2191	25·9
·2	1·1163	15·0	34·0	1·1491	18·7	·8	1·1835	22·3	·6	1·2196	25·9
·3	1·1168	15·1	·1	1·1496	18·7	·9	1·1840	22·4	·7	1·2201	26·0
·4	1·1172	15·1	·2	1·1501	18·8	41·0	1·1846	22·4	·8	1·2207	26·0
·5	1·1177	15·2	·3	1·1506	18·85	·1	1·1851	22·5	·9	1·2212	26·1
·6	1·1182	15·2	·4	1·1511	18·9	·2	1·1856	22·5	48·0	1·2218	26·1
·7	1·1187	15·3	·5	1·1516	18·95	·3	1·1861	22·6	·1	1·2223	26·2
·8	1·1191	15·3	·6	1·1521	19·0	·4	1·1866	22·65	·2	1·2229	26·2
·9	1·1196	15·4	·7	1·1526	19·1	·5	1·1872	22·7	·3	1·2234	26·3
28·0	1·1201	15·4	·8	1·1531	19·1	·6	1·1877	22·75	·4	1·2240	26·35
·1	1·1206	15·5	·9	1·1536	19·2	·7	1·1882	22·8	·5	1·2245	26·4
·2	1·1210	15·55	35·0	1·1541	19·2	·8	1·1887	22·9	·6	1·2250	26·45
·3	1·1215	15·6	·1	1·1540	19·3	9	1·1892	22·9	·7	1·2256	26·5
·4	1·1220	15·7	·2	1·1551	19·3	42·0	1·1898	23·0	·8	1·2261	26·6
·5	1·1225	15·7	·3	1·1556	19·4	·1	1·1903	23·0	·9	1·2267	26·6
·6	1·1229	15·8	·4	1·1561	19·4	·2	1·1908	23·1	49·0	1·2272	26·7
·7	1·1234	15·8	·5	1·1566	19·5	·3	1·1913	23·1	·1	1·2278	26·7
·8	1·1239	15·9	·6	1·1571	19·55	·4	1·1919	23·2	·2	1·2283	26·8
·9	1·1244	15·9	·7	1·1576	19·6	·5	1·1924	23·2	·3	1·2289	26·8
29·0	1·1248	16·0	·8	1·1581	19·65	·6	1·1929	23·3	·4	1·2294	26·9
·1	1·1253	16·0	·9	1·1586	19·7	·7	1·1934	23·3	·5	1·2300	26·9
·2	1·1258	16·1	36·0	1·1591	19·8	·8	1·1940	23·4	·6	1·2305	27·0
·3	1·1263	16·1	·1	1·1596	19·8	·9	1·1945	23·45	·7	1·2311	27·0
·4	1·1267	16·2	·2	1·1601	19·9	43·0	1·1950	23·5	·8	1·2316	27·1
·5	1·1272	16·25	·3	1·1606	19·9	·1	1·1955	23·55	·9	1·2322	27·1
·6	1·1277	16·3	·4	1·1611	20·0	·2	1·1961	23·6	50·0	1·2327	27·2
·7	1·1282	16·4	·5	1·1616	20·0	·3	1·1966	23·7	·1	1·2333	27·2
·8	1·1287	16·4	·6	1·1621	20·1	·4	1·1971	23·7	·2	1·2338	27·3
·9	1·1291	16·5	·7	1·1626	20·1	·5	1·1976	23·8	·3	1·2344	27·3
30·0	1·1296	16·5	·8	1·1631	20·2	·6	1·1982	23·8	·4	1·2349	27·4
·1	1·1301	16·6	·9	1·1636	20·2	·7	1·1987	23·9	·5	1·2355	27·45
·2	1·1306	16·6	37·0	1·1641	20·3	·8	1·1992	23·9	·6	1·2361	27·5
·3	1·1311	16·7	·1	1·1646	20·35	·9	1·1998	24·0	·7	1·2366	27·55
·4	1·1315	16·7	·2	1·1651	20·4	44·0	1·2003	24·0	·8	1·2372	27·6
·5	1·1320	16·8	·3	1·1656	20·5	·1	1·2008	24·1	·9	1·2377	27·7
·6	1·1325	16·85	·4	1·1661	20·5	·2	1·2013	24·1	51·0	1·2383	27·7
·7	1·1330	16·9	·5	1·1666	20·6	·3	1·2019	24·2	·1	1·2388	27·8
·8	1·1335	17·0	·6	1·1671	20·6	·4	1·2024	24·2	·2	1·2394	27·8
·9	1·1340	17·0	·7	1·1676	20·7	·5	1·2029	24·3	·3	1·2399	27·9
31·0	1·1344	17·1	·8	1·1681	20·7	·6	1·2035	24·35	·4	1·2405	27·9
·1	1·1349	17·1	·9	1·1686	20·8	·7	1·2040	24·4	·5	1·2411	28·0
·2	1·1354	17·2	38·0	1·1692	20·8	·8	1·2045	24·45	·6	1·2416	28·0
·3	1·1359	17·2	·1	1·1697	20·9	·9	1·2051	24·5	·7	1·2422	28·1
·4	1·1364	17·3	·2	1·1702	20·9	45·0	1·2056	24·6	·8	1·2427	28·1
·5	1·1369	17·3	·3	1·1707	21·0	·1	1·2061	24·6	·9	1·2433	28·2

TABLE SHOWING THE RELATION OF PERCENTAGES, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
52·0	1·2439	28·2	58·8	1·2828	31·7	65·6	1·3235	35·2	72·4	1·3661	38·5
·1	1·2444	28·3	·9	1·2834	31·8	·7	1·3241	35·25	·5	1·3667	38·6
·2	1·2450	28·3	59·0	1·2840	31·85	·8	1·3247	35·3	·6	1·3674	38·6
·3	1·2455	28·4	·1	1·2845	31·9	·9	1·3253	35·35	·7	1·3680	38·7
·4	1·2461	28·4	2	1·2851	31·95	66·0	1·3260	35·4	·8	1·3687	38·7
·5	1·2467	28·5	·3	1·2857	32·0	·1	1·3266	35·4	·9	1·3693	38·8
·6	1·2472	28·5	·4	1·2863	32·05	·2	1·3272	35·5	73·0	1·3699	38·8
·7	1·2478	28·6	·5	1·2869	32·1	·3	1·3278	35·5	·1	1·3705	38·9
·8	1·2483	28·65	·6	1·2875	32·15	·4	1·3285	35·6	·2	1·3712	38·9
·9	1·2489	28·7	·7	1·2881	32·2	·5	1·3291	35·6	·3	1·3719	39·0
53·0	1·2495	28·75	·8	1·2887	32·3	·6	1·3297	35·7	·4	1·3725	39·0
·1	1·2500	28·8	·9	1·2893	32·3	·7	1·3303	35·7	·5	1·3732	39·1
·2	1·2506	28·85	60·0	1·2898	32·4	·8	1·3309	35·8	·6	1·3738	39·1
·3	1·2512	28·9	·1	1·2904	32·4	·9	1·3315	35·8	·7	1·3745	39·2
·4	1·2517	28·9	·2	1·2910	32·5	67·0	1·3322	35·9	·8	1·3751	39·2
·5	1·2523	29·0	·3	1·2916	32·5	·1	1·3327	35·9	·9	1·3757	39·3
·6	1·2529	29·1	·4	1·2922	32·6	·2	1·3334	36·0	74·0	1·3764	39·3
·7	1·2534	29·1	·5	1·2928	32·6	·3	1·3340	36·0	·1	1·3770	39·4
·8	1·2540	29·2	·6	1·2934	32·7	·4	1·3346	36·1	·2	1·3777	39·4
·9	1·2546	29·2	·7	1·2940	32·7	·5	1·3352	36·1	·3	1·3783	39·5
54·0	1·2551	29·3	·8	1·2946	32·8	·6	1·3359	36·2	·4	1·3790	39·5
·1	1·2557	29·3	·9	1·2952	32·8	·7	1·3365	36·2	·5	1·3796	39·6
·2	1·2563	29·4	61·0	1·2958	32·9	·8	1·3371	36·3	·6	1·3803	39·6
·3	1·2568	29·4	·1	1·2964	32·9	·9	1·3377	36·3	·7	1·3809	39·7
·4	1·2574	29·5	·2	1·2970	33·0	68·0	1·3384	36·4	·8	1·3816	39·7
·5	1·2580	29·5	·3	1·2975	33·0	·1	1·3390	36·4	·9	1·3822	39·8
·6	1·2585	29·6	·4	1·2981	33·1	·2	1·3396	36·5	75·0	1·3828	39·8
·7	1·2591	29·6	·5	1·2987	33·1	·3	1·3402	36·5	·1	1·3835	39·9
·8	1·2597	29·7	·6	1·2993	33·2	·4	1·3408	36·6	·2	1·3842	39·9
·9	1·2602	29·7	·7	1·2999	33·2	·5	1·3415	36·6	·3	1·3848	40·0
55·0	1·2608	29·8	·8	1·3005	33·3	·6	1·3421	36·7	·4	1·3855	40·0
·1	1·2614	29·8	·9	1·3011	33·3	·7	1·3427	36·7	·5	1·3861	40·1
·2	1·2620	29·9	62·0	1·3017	33·4	·8	1·3433	36·8	·6	1·3868	40·1
·3	1·2625	29·9	·1	1·3023	33·4	·9	1·3440	36·8	·7	1·3874	40·2
·4	1·2631	30·0	·2	1·3029	33·5	69·0	1·3446	36·9	·8	1·3880	40·2
·5	1·2637	30·05	·3	1·3035	33·5	·1	1·3452	36·9	·9	1·3887	40·3
·6	1·2642	30·1	·4	1·3041	33·6	·2	1·3458	37·0	76·0	1·3894	40·3
·7	1·2648	30·15	·5	1·3047	33·6	·3	1·3465	37·0	·1	1·3900	40·4
·8	1·7654	30·2	·6	1·3053	33·7	·4	1·3471	37·1	·2	1·3907	40·4
·9	1·2660	30·25	·7	1·3059	33·7	·5	1·3477	37·1	·3	1·3913	40·5
56·0	1·2665	30·3	·8	1·3065	33·8	·6	1·3484	37·2	·4	1·3920	40·5
·1	1·2671	30·4	·9	1·3071	33·8	·7	1·3490	37·2	·5	1·3926	40·6
·2	1·2677	30·4	63·0	1·3077	33·9	·8	1·3496	37·3	·6	1·3933	40·6
·3	1·2683	30·5	·1	1·3083	33·9	·9	1·3502	37·3	·7	1·3940	40·7
·4	1·2688	30·5	·2	1·3085	34·0	70·0	1·3509	37·4	·8	1·3946	40·7
·5	1·2694	30·6	·3	1·3095	34·0	·1	1·3515	37·4	·9	1·3953	40·8
·6	1·2700	30·6	·4	1·3101	34·1	·2	1·3521	37·5	77·0	1·3959	40·8
·7	1·2706	30·7	·5	1·3107	34·1	·3	1·3528	37·5	·1	1·3966	40·8
·8	1·2712	30·7	·6	1·3113	34·2	·4	1·3534	37·6	·2	1·3972	40·9
·9	1·2717	30·8	·7	1·3119	34·2	·5	1·3540	37·6	·3	1·3979	41·0
57·0	1·2723	30·8	·8	1·3126	34·3	·6	1·3546	37·7	·4	1·3986	41·0
·1	1·2729	30·9	·9	1·3132	34·3	·7	1·3553	37·7	·5	1·3992	41·0
·2	1·2735	30·9	64·0	1·3138	34·4	·8	1·3559	37·8	·6	1·3999	41·1
·3	1·2740	31·0	·1	1·3144	34·4	·9	1·3565	37·8	·7	1·4005	41·1
·4	1·2746	31·0	·2	1·3150	34·5	71·0	1·3572	37·9	·8	1·4012	41·2
·5	1·2752	31·1	·3	1·3156	34·5	·1	1·3578	37·9	·9	1·4019	41·2
·6	1·2758	31·1	·4	1·3162	34·6	·2	1·3585	38·0	78·0	1·4025	41·3
·7	1·2764	31·2	·5	1·3168	34·6	·3	1·3591	38·0	·1	1·4032	41·3
·8	1·2769	31·2	·6	1·3174	34·7	·4	1·3597	38·1	·2	1·4039	41·4
·9	1·2775	31·3	·7	1·3180	34·7	·5	1·3604	38·1	·3	1·4045	41·4
58·0	1·2781	31·3	·8	1·3186	34·8	·6	1·3610	38·2	·4	1·4052	41·5
·1	1·2787	31·4	·9	1·3192	34·8	·7	1·3616	38·2	·5	1·4058	41·5
·2	1·2793	31·4	65·0	1·3198	34·9	·8	1·3623	38·2	·6	1·4065	41·6
·3	1·2799	31·5	·1	1·3205	34·95	·9	1·3629	38·3	·7	1·4072	41·6
·4	1·2804	31·5	·2	1·3211	35·0	72·0	1·3635	38·3	·8	1·4078	41·7
·5	1·2810	31·6	·3	1·3217	35·05	·1	1·3642	38·4	·9	1·4085	41·7
·6	1·2816	31·6	·4	1·3223	35·1	·2	1·3648	38·4	79·0	1·4092	41·8
·7	1·2822	31·7	·5	1·3229	35·15	·3	1·3655	38·5	·1	1·4098	41·8

Table showing the Relation of Percentages, &c.—*continued.*

Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.	Per cent. of Sugar.	Specific Gravity.	Degree Baumé.
79·2	1·4105	41·9	81·0	1·4226	42·7	82·7	1·4341	43·5	84·4	1·4457	44·3
·3	1·4112	41·9	·1	1·4232	42·8	·8	1·4348	43·6	·5	1·4464	44·4
·4	1·4119	42·0	·2	1·4239	42·8	·9	1·4354	43·6	·6	1·4471	44·4
·5	1·4125	42·0	·3	1·4246	42·9	83·0	1·4361	43·7	·7	1·4478	44·5
·6	1·4132	42·1	·4	1·4253	42·9	·1	1·4368	43·7	·8	1·4485	44·5
·7	1·4138	42·1	·5	1·4259	43·0	·2	1·4375	43·8	·9	1·4492	44·6
·8	1·4145	42·2	·6	1·4266	43·0	·3	1·4382	43·8	85·0	1·4498	44·6
·9	1·4152	42·2	·7	1·4273	43·1	·4	1·4388	43·9	·1	1·4505	44·7
80·0	1·4158	42·2	·8	1·4280	43·1	·5	1·4395	43·9	·2	1·4512	44·7
·1	1·4165	42·3	·9	1·4287	43·2	·6	1·4402	44·0	·3	1·4519	44·8
·2	1·4172	42·3	82·0	1·4293	43·2	·7	1·4409	44·0	·4	1·4526	44·8
·3	1·4179	42·4	·1	1·4300	43·3	·8	1·4416	44·1	·5	1·4533	44·9
·4	1·4185	42·4	·2	1·4307	43·3	·9	1·4423	44·1	·6	1·4540	44·9
·5	1·4192	42·5	·3	1·4314	43·4	84·0	1·4430	44·2	·7	1·4547	45·0
·6	1·4199	42·5	·4	1·4320	43·4	·1	1·4437	44·2	·8	1·4554	45·0
·7	1·4205	42·6	·5	1·4327	43·5	·2	1·4443	44·3	·9	1·4561	45·1
·8	1·4212	42·6	·6	1·4334	43·5	·3	1·4450	44·3	86·0	1·4568	45·1
·9	1·4219	42·7									

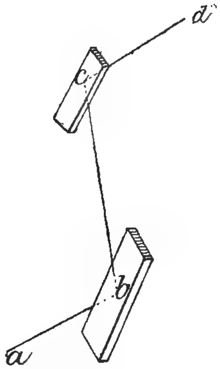
The preceding table gives the proportions of sugar present in the juice as indicated by the sp. gr. or the degrees B. of the solution. The B. degrees are more frequently used in sugar-factories than the actual sp. gr., and this table gives the data for the comparison between the two. In either case, the sp. gr. or B. may be determined by the sp. gr. bottle or the hydrometer spindle, and if the usual precautions are taken, the results are directly comparable. The sp. gr. bottle is of course the more correct method of the two. When still greater accuracy is necessary, the juice has to be treated in a similar way to that in which the solutions of sugar have already been directed to be treated, viz. 16·35 *cc.* of the juice are measured into a 100-*cc.* flask, subacetate of lead is added, and if necessary sulphite of soda, the solution is made up to 100 *cc.*, and, after admixture, filtered and polarized, as before directed. Cane- and beet-juice require a larger addition of basic acetate of lead, on account of the gummy and mucilaginous matters which they contain.

Beet Analysis.—The analysis of beet-juice is like that of beet-sugar. When beet itself is to be analysed, special precautions have to be taken, in order to obtain a fair sample. It is necessary to wash free from mechanical impurities, and to remove the top and small rootlets, and then dry the root. Occasionally it is desirable to determine the difference of weight in the root before and after this treatment, as the amount of mechanical impurities may be excessive. This is not often the case. To obtain a fair sample of the produce of a field, it is absolutely essential to take a considerable number of roots, which should be selected so as to differ in size and outward appearance. It is sometimes more satisfactory to sample the roots by taking a large boring out of each by means of an instrument similar to a cheese-taster. The whole of the samples taken out must then be sliced, shredded, and mixed, and an average sample taken for analysis. It is generally recommended that the estimation of the sugar in the root should be taken by pulping a large weight (200–300 *grm.*) of the cores cut out from the roots, and pressing them so as to express the juice in a small filter-press or filter-bag. This appears to involve a considerable risk of error, inasmuch as the pulping cannot be effectual without a certain loss of juice, which is of considerable importance in a small sample such as that worked upon. It seems far preferable to pulp a portion of the sample (not less than 100 *grm.*), transfer it to a piece of thin muslin tied up so as to form a bag, and boil for one or two minutes in a beaker or other suitable vessel, withdrawing the bag and squeezing out the superfluous liquid, decanting the total liquid into another vessel, and repeating the operation in the same way 3–5 times, as may be necessary, boiling the residue in the last instance for 5–10 minutes, so as to remove as far as possible the last residue of soluble matters, and, after squeezing, rinsing the muslin bag containing the marc once more with water. A solution obtained in this way will necessarily be a dilute one, and if too dilute, it will be requisite to concentrate it before titrating for glucose, or using for the estimation of cane-sugar. If so, the concentration must be effected by slow evaporation on the water bath, so as not to convert any of the cane-sugar into glucose. After concentration, the analysis is carried out as before directed.

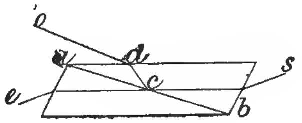
Sugar-cane Analysis.—A correct estimation of the amount of sugar obtainable from sugar-canes is even more difficult than in the case of beet-roots; the best plan to be pursued is unquestionably as follows. Obtain a true sample of the canes of not less than 4–6 lb. in weight, but drawn in such a way as to obtain a fair proportion of the joints in the canes, so as to faithfully represent the whole of the sample itself. Slice the canes longitudinally with a sharp knife, making at least 3 or 4 cuts, so as to divide them into narrow pieces or slips not more than ½–⅝ in. diam. Pass these pieces between the rollers of a hand roller-press provided with a tray underneath and a spout to carry away the liquid which is pressed out. After passing the pieces through twice, increasing the pressure on the second occasion, dip them into hot water for a few seconds, so as to moisten them, and pass again through the press 2 or 3 times, still increasing the pressure each time. The begass or trash brought out should not contain more than about 15 per cent. of moisture, if the operation has been properly performed. When this has been done, the liquid pressed out is in a state fit for analysis, and this may be carried through at once on the liquid, calculations being made on the dry material, i. e. the sugar-cane originally put into the press.

Determination of Sugars—Optical Methods—Polarized Light.—When a ray of light *a b* (Fig. 1413) falls upon a polished surface of glass or other non-metallic substance, inclined to an angle of 35° 20′, the reflected ray is altered in character, and acquires peculiar properties: it is in fact said to be "polarized." In order to show the character of the change which has been produced in the ray of light, the polarized ray may be received at *c* upon a second reflecting surface fixed at the same angle to the already reflected ray. If the two reflecting surfaces are parallel one to another, the polarized ray will be reflected again; but if the second reflector is rotated around the axis *c d* until the reflecting planes are perpendicular to each other, no light is reflected, and, at intermediate points in the rotation, the amount of reflection differs. If the angle *a b c* differs within moderate limits from 35° 20′, some portion of the light is polarized, but the maximum effect is obtained only at this angle. The angle, however, differs for different substances;—thus for water it is 36° 49′, and for quartz 32° 28′.

1413.



The light may also be polarized by refraction. Calc-spar and all other doubly-refracting crystals have the power of polarizing light. A ray of ordinary light passed through a crystal of calc-spar, in any direction except its optical axis, is divided into 2 beams of equal intensity, called the ordinary and extraordinary rays. By a suitable adjustment of the position of the prism, it is of course easy to throw the ordinary ray entirely out of the field of view of the optical instrument in which it is to be used, and if the extraordinary ray is then passed through a second rhomb of calc-spar, it experiences double refraction, giving rise to 2 beams of unequal intensity, and the 2 rays resulting from the double refraction are found to be polarized. Tourmaline, selenite, and other crystalline bodies, as well as glass, when submitted to strains or pressure, become double-refracting. A plane of polarized light is that in which the ray incident at the polarizing angle is reflected or transmitted in the greatest degree, and it is obvious that when the polarization has been produced by refraction, the plane of polarization is parallel to the plane of refraction.



1414.

The Nichol prism, which is probably the most valuable device used for producing polarized light, or analyzing it, consists of a rhomb of calc-spar slit along the plane passing through the shorter diagonal; the two halves are cemented together again with Canada-balsam, the refracting index of which is intermediate between that of the extraordinary and ordinary indices of the crystal. The result of this arrangement is that when the ray of light *s* (Fig. 1414) enters the prism, the ordinary ray is totally reflected on the surface of the internal layer of balsam *a b*, and is refracted out of the crystal in the direction *c d o*, while the extraordinary ray *c e* emerges alone in a direction not differing greatly from that of the principal axis of the crystal itself.

When a ray of light in which a state of circular polarization has been produced is refracted by a Nichol prism, and viewed through an analyzer, the rotation of the analyzer causes no variation in the intensity of the light; but this circular polarized light is not identical with ordinary light, as may be proved by interposing a plate of selenite in the course of the ray, when the light becomes elliptically polarized. Rotation of the plane of polarization of crystals of quartz or calc-spar causes a rotation of the polarization-plane around its axis. There are 2 varieties of quartz, known as right-handed and left-handed, one of which rotates the plane of polarization to the right, and the other to the left. If a plane of quartz cut perpendicularly to its axis is placed between the analyzer and the polarizer, the ray of polarized light is rotated, and, instead of being white, is coloured, the tints of colour changing in the order of the colours of the spectrum as the analyzer is turned. If monochromatic light is used instead of white light, it is found that when the Nichol prisms are adjusted so as to produce darkness, corresponding to total extinction of the ray of light, the introduction of the plate of quartz in the course of the ray partially restores the light, but total extinction is again produced on rotating the analyzer. The angular rotation which has been experienced by the ray may be measured by the degree to which it is necessary to rotate the analyzer to produce this effect.

Two facts must be borne in mind here. The angle of rotation is directly proportional to the thickness of the quartz, and it varies for the different rays of the spectrum, being greater for those rays which are more refrangible, as shown by the following table, which gives the rotations produced by a quartz plate 1 *mm.* thick:—

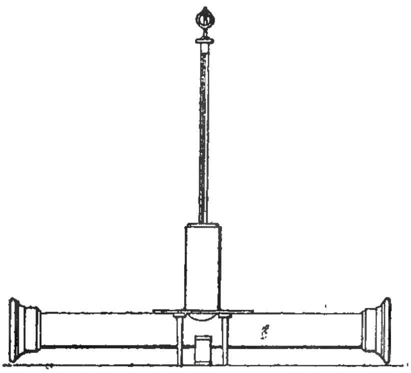
Red	19°	Blue	32°
Orange	21°	Indigo	36°
Yellow	23°	Violet	41°
Green	28°		

Polariscopes or Optical Saccharometers.—Solutions of cane-sugars as well as many other bodies possess the property of deviating the course of a ray of polarized light in a fixed and definite degree. Other sugars deviate the course of this ray to degrees which differ not only in amount but in direction. Thus cane-sugar and dextrose deviate the plane of rotation to the right, while lævulose and other sugars deviate it to the left. It has consequently been possible to construct instruments in which, by measuring the degree of rotation or deviation produced by a solution contained in a tube of a certain length, it is easy to determine the percentage of sugar present, because by numerous experiments it has been proved that the angular rotation produced by different sugars is directly proportional (within certain limits of error, controlled by well-understood circumstances) to the bodies present.

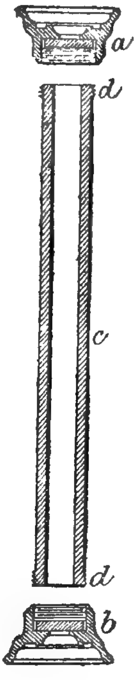
The "polariscopes," as they are called, i. e. optical saccharometers of different makers are here described. The three instruments in common use are the Soleil-Ventzke, Soleil-Duboscq, and Shadow (Penombre).

In construction, the Soleil polariscope is simple. The tube which contains the liquor consists of 3 parts (Fig. 1415), of which, 2 parts *a b* are capable of being screwed on to the remaining portion *c*, which consists of a glass tube encased in metal, the ends of the tube being carefully ground off to an exact length of 20 *centim.*, and provided with screws *d*. Two small flat pieces of glass are arranged to cover the ends of this tube, and these are secured in place by the caps *a b*, which are furnished with internal screws fitting on to the screws of the central part *c*. This provides for a column of liquid contained in the tube exactly 20 *centim.* long. Another tube of the same kind, but 22 *centim.* long, is requisite for use in those cases in which sugar solutions have to be inverted. This tube is preferably constructed as in Fig. 1416, with an outlet or T-piece rising from the centre of the tube, through which a thermometer can be passed to ascertain the exact temperature of the contents of the tube, the instrument being so arranged that this tube can be dropped in between the eye-piece and objective.

1416.



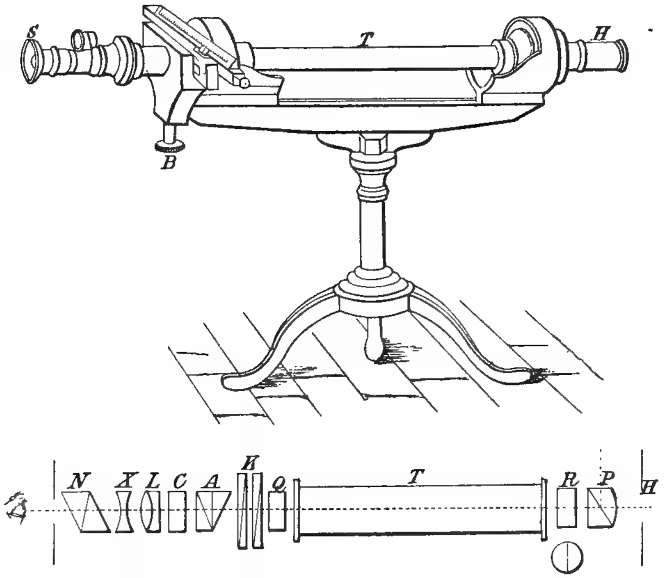
1415.



The instrument consists of 2 distinct portions, one designed to polarize the light, and the other to analyze or test the character of the ray of light passing through the solution contained in the tube, both of which are capable of rotation, the former, i. e. the objective, to a small extent only, and the latter through the complete circle. This latter portion of the instrument is, according to the character of the polariscope, furnished with a graduated circle for indicating the degree of rotation, or with a divided scale showing the thickness of the quartz, hereafter referred to, which has been introduced between the sugar solution and the eye. The optical part of the instrument, as well as its general form, is shown in Fig. 1417.

The Soleil-Duboscq polariscope consists of 2 metallic tubes mounted on a tripod. The light enters at H by a circular opening having a diameter of 3 *mm.*, and traverses the achromatic polarizing prism P. R is a plate of quartz called the plate of double rotation, composed of 2 half-discs of quartz of equal thickness, cut perpendicularly to the axis of crystallization, turned in opposite directions, and cemented together so that the plane of separation is in a vertical direction. The half-discs have contrary rotations, one being left-handed and the other right-handed. The light then passes on to the tube T containing the solution to be examined, and encounters Q, a quartz plate either right-handed or left-handed, of arbitrary thickness. From Q, the ray reaches K, which are wedge-shaped quartz plates having the same kind of rotation, but differing from that of Q. These are fixed in brass slides, covered with plain brass plates on each side, so as to protect them from injury. They are so fixed that they can be moved to and fro at will, and by this means the optical thickness of the quartz through which the polarized rays have to pass may be increased or diminished. The light then passes to the analyzer A and quartz plate C; a telescope X L defines the field of view of the instrument. The doubly-refracting prism N is placed relatively to the diaphragm of the telescope, in such a way that the passage of one of the rays transmitted by the polarizer is intercepted. Either the ordinary or the extraordinary ray, according to the thickness of the quartz-plate, will pass through. From the construction of this apparatus, it is evident that on making an observation through the ocular or eye-piece, there will appear a luminous disc with a vertical line in its centre, the latter being produced by the junction of the 2 quartz plates R. The sum of the thickness of the two prismatic quartz-plates at a certain position is exactly equal to that of Q, and as the rotations are different, one being right- and the other left-handed, it follows that they neutralize one another, and produce no change of colour on the polarized ray.

1417.



When the instrument is properly adjusted, and the tube filled with distilled water, each side of the field will be of the same colour. The tube containing the distilled water is now withdrawn, and another tube containing a liquid having a rotatory power which will act on polarized light is introduced. The uniformity of the colour will be destroyed, owing to the rotatory effect of the liquid itself, which vitiates the compensatory effects of the plate R and the quartz wedges.

The direction in which the ray of light is rotated will depend upon the character of the liquid. Thus with cane-sugar, the deviation will be to the right, and this, with that of the right-handed plate of quartz, produces an inequality in the polarizer, and consequently the production of unequal colour in the two halves of the field.

The only way to restore the field to uniformity is by turning the screw, by which the quartz-wedges are moved to and fro, whereby the thickness of the quartz is increased or diminished. This increase or diminution compensates for the deviating effect of the liquid, and shows the degree to which the ray of light has been rotated. The action of the compensator also shows whether the substance examined is right or left rotating.

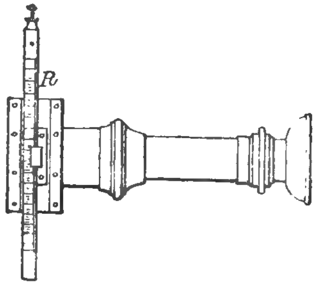
The degree of rotation is measured by the thickness of quartz necessary to neutralize the deviation of the body examined. This thickness is estimated by a graduated scale fixed to one of the slides R (Fig. 1418), in such a way that the one carrying the scale is read off upon the other serving as an indicator.

In the instrument as ordinarily constructed, the scale is graduated into degrees indicating percentages of sugar on each side of the zero division.

A thickness of quartz equal to $\frac{1}{100}$ *mm.* is equivalent to a displacement of 1 division on the scale, compensating a rotatory effect of 1 per cent. of sugar when the solution is made of the proper strength.

This polariscope has been greatly improved over its original form by placing in front of the ocular of the telescope a Nichol prism N capable of rotation. This arrangement is for the purpose of producing what is called the sensitive tints, i. e. that tint in which the change from one colour to another is most readily appreciated by the eye. The colour of the liquid under examination is to a considerable extent destroyed by this prism.

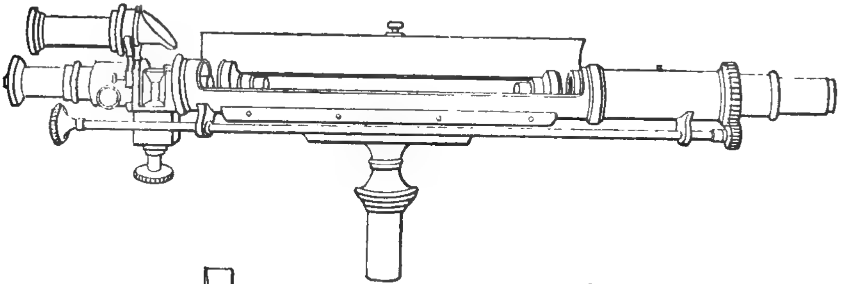
1418.

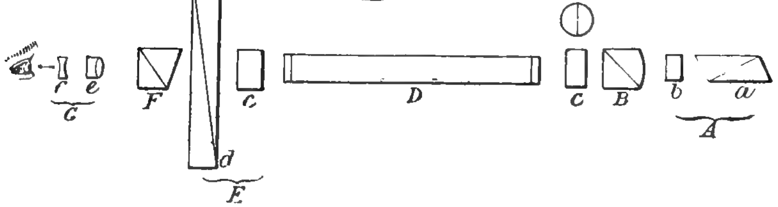


The zero point is determined by filling one of the tubes with distilled water, putting it into position, observing the reading, focussing, and then adjusting by means of the screw B.

Fig. 1419 gives a perspective view of the Soleil-Ventzke Saccharometer in its most improved form, and Fig. 1420 the section of the optical arrangement. A support standing on a tripod holds the main portion of the apparatus, the middle part of which consists of a metallic receptacle, provided with a hinged cover to prevent access of light while an observation is being taken. At each end of this support, a brass tube is fixed, one containing the double quartz plate *d* and the polarizer *c*. A is the regulator for changing the tints of the double quartz plates C. It consists of the Nichol prism *a* and quartz plates *b*, cut perpendicularly to the axis of the crystal, both of which can be caused to rotate by appropriate means. B, the polarizer, is an achromatic calc-spar prism. As its principal section is vertical, the extraordinary ray is totally reflected at the axis and only the ordinary ray is transmitted. The convex surface turned towards A renders the rays parallel. The double quartz plate C is precisely similar to that of the Soleil-Duboscq apparatus. Its thickness may be either 3·75 *mm.* or 7·50 *mm.* D is the observation tube. The compensator E

1419.



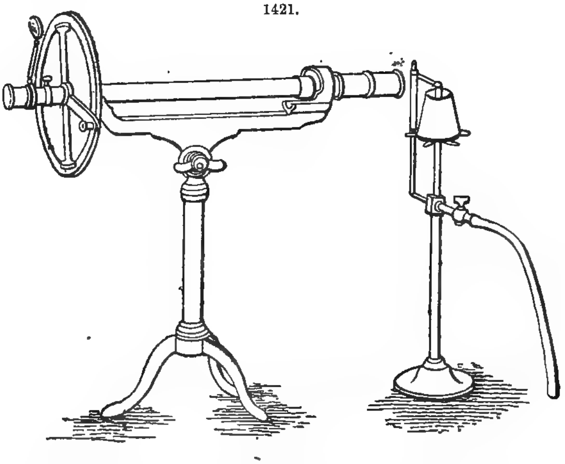


1420.

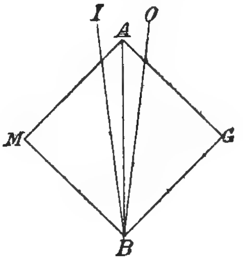
consists of the right-handed plate of quartz *c*, and the wedge-form plates *d*, which are left-handed, one being fixed and the other movable by means of a rack and pinion, to increase or diminish the thickness of crystal through which the polarized ray has to pass; *c* may be of left-handed quartz, but in that case the optical rotation of the wedges must be in an opposite sense. The analyzer F is an achromatic calc-spar prism, whose principal section must be parallel to that of the polarizer B when the thickness of the plate C is 3·75 *mm.*, or perpendicular to it when the latter is double that thickness. G is a small Galilean telescope, consisting of objective *e* and ocular *f*.

The Shadow polariscope is constructed as follows. It possesses certain peculiarities, the principal of which is that the field of the optical part of the instrument appears to the eye to be divided into two halves, one light and one dark (in shade, not tint or colour), divided by a vertical line, and the analyzer has to be rotated till the two portions of the field appear of the same shade. The apparatus was devised by Duboscq and Cornu, and is shown in Fig. 1421. The polarizing prism consists of a rhomb of calc-spar, divided longitudinally, following the plane of the smaller diagonal A B, as shown in Fig. 1422. Each of the cut faces being removed for an angle of 2½°, the remaining sections I B M and O B G are cemented together again on the planes passing through B I and B O. A double prism is produced by this means, the principal sections having an angle of 5°; the effect of this is that small changes in the illuminating field produce relatively large changes in rotation in the ray of polarized light, and the analyzer has to be rotated relatively to a large extent to neutralize the effect. This increases the delicacy of the instrument. If the prisms are not properly adjusted, they are rectified by turning the Nichol prism by means of a button, until the whole field becomes of a uniform slate or French-grey colour, and the zero of the scale exactly corresponds to that of the Vernier. When this is the case, the instrument is in proper adjustment, and ready for use.

1421.



1422.



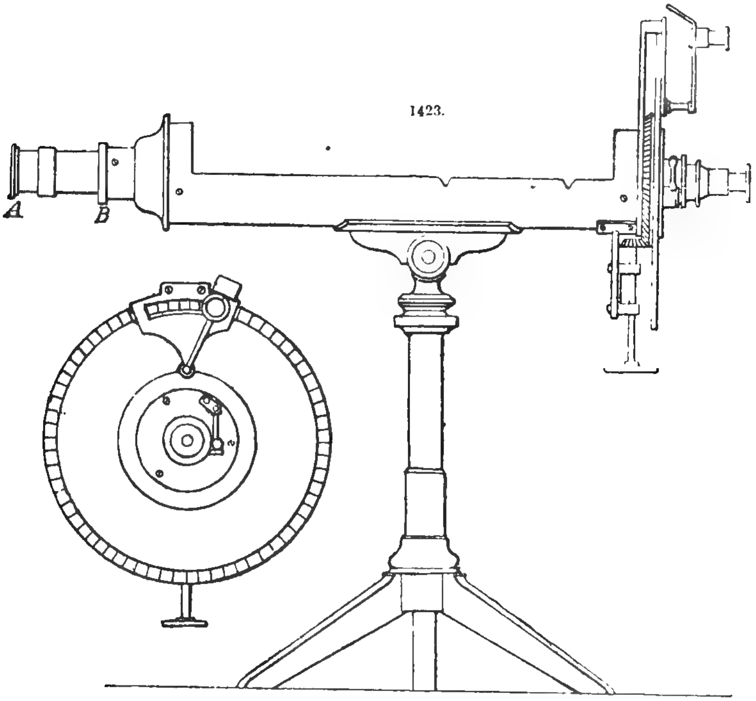
The observation is made in the same way as in the last polariscope mentioned, with the exception that the ocular analyzer is rotated instead of being moved in a transverse direction to the field of view.

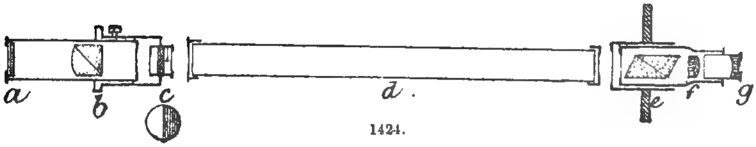
In analyzing a sample, the arm is rotated until the field assumes a uniform tint, and the difference between the two sides of the field of view has disappeared, the vertical line alone remaining. At this point, the rotation is stopped, and the scale is read.

This polariscope is much employed in France. It is very accurate, moderate in price, and on the whole one of the most useful. A great advantage which it possesses is that persons who are wholly or partially colour-blind can read it with reasonable if not perfect accuracy. The light needed for it is monochromatic, and may be obtained by means of the Laurent lamp, or any other lamp which introduces a sodium compound into the flame of a Bunsen burner.

The optical parts of Laurent's polariscope differ considerably from those last described. Figs. 1423, 1424, show the construction of the apparatus; *a* is a thin plate of bichromate of potash, inserted to cut off any blue or violet rays in the sodium light which is used for the purpose, so as to render it more thoroughly monochromatic.

The polarizer *b* is a calc-spar prism, both parts being placed in a movable brass tube *a b* (Fig. 1424); *c* is a round diaphragm covered by a plate of glass, on which a thin section of quartz is cemented, the quartz being cut in such a way that only half the aperture is covered by it; *e* is the analyzing Nichol, and *f g* the lenses of the telescope. The theory of this saccharometer is as follows. Supposing the plane of polarization to be vertical to the optical axis of the quartz plate, the light will traverse it without deviation; if the analyzer is rotated, advance is made progressively to the maximum or total extinction of the light; consequently, by turning the analyzer through any given angle to the right, the plane of polarization being no longer parallel to the axis of the crystal, the polarized ray will pass without deviation on the right side on which there is no quartz, but it will be deviated on the left, and on this side there will be determined a principal section symmetrical to that of the polarizer on the right side, but turning to the left. If the analyzer be now turned until the principal section is perpendicular to that of the polarizer, there will be a total extinction of the light to the right, but only partial to the left. If, on the contrary, the principal section of the analyzer is perpendicular to that which corresponds to that of the quartz plate, there will be a total extinction to the left and partial to the right. Finally, if the principal section of the analyzer is intermediate in position, i. e. perpendicular to the axis of the crystal, or horizontal, there will be partial extinction of the light both to the right and left, and the luminous disc sighting the field of the instrument will appear uniformly obscured. Hence a small rotation of the analyzer tends to change the uniformity of the shade, and renders this polariscope specially delicate with small angles. The distinctive peculiarity of this instrument is that by turning A B (Fig. 1423), the angle of rotation is augmented, and by this means the field is greatly brightened, and observation may be made with darker solutions than can otherwise be used.


1423.



1424.

This polariscope has been adopted for use in the French Government laboratories for sugar analysis; although it is stated that recently some very considerable modifications have been made in it, mainly in the direction of working with observation-tubes of 1 or even 2 *m.* in length, and in the graduation so as to enable small proportions of sugar to be estimated more conveniently.

Specific Rotatory Power.—The peculiar tint called the "transition" tint (*teint de passage*) is produced when a ray of light is caused to pass through a quartz plate 3·75 *mm.* thick. The tint is perhaps best described as rose-purple of a somewhat delicate character, but it is easily altered by the slightest movement in the position of the analyzer. To most persons who are not colour-blind, this is a most delicate colour for detecting changes in the shades of tint produced by polarization.

The mode in which the specific rotatory power of liquids is measured is somewhat peculiar. It follows from what has been said that the rotation is directly proportionate to the length of the column of liquids through which the ray passes, and is also proportional, sometimes directly and sometimes indirectly, to the quantity of active substance dissolved in the liquid. If e be the amount of substance dissolved in a unit of weight of the solution, l the length of the liquid column, and a the observed angle of rotation for any particular column, at the transition tint the angle of rotation for the unit of length will be $\frac{a}{e\,l}$; but as the solution of the optically active body is often attended with alteration of volume, it is desirable, in order to obtain an expression independent of such irregularities, to refer the observed angle of deviation to a hypothetical unit of density—that is to divide the quantity $\frac{a}{e\,l}$ by the density g of the solution. The expression $[a]\,j = \frac{a}{e\,l\,g}$ is called the specific rotatory power, and represents the angle of deviation which the pure substance in a column of the unit of length and density 1 would impart to the ray corresponding to the transition tint. For instance, a solution containing 0·155 *grm.* of cane-sugar to 1 *grm.* of liquid has a sp. gr. of 1·06, and deflects the polarized ray for the transition tint 24° in a tube 20 *mm.* long. The specific rotatory power is therefore

$$[a]\,j = \frac{24}{155 \times 20 \times 1{\cdot}06} = 7{\cdot}3^\circ.$$

$[a]$ is the expression for the specific rotatory power in general; a letter affixed shows the particular ray of the spectrum at which the deviation was observed, thus $[a]$ D and $[a]\,j$ are the expressions for the line D of the spectrum, and for the mean yellow ray or transition tint respectively. The minus sign is prefixed to the degree when the substance rotates to the left.

The following table shows the equivalence in degrees of different polariscopes:—

		Grm. Sugar in 100 *cc.*
1° Scale of Mitscherlich	=	·750
1° " Soleil-Duboscq	=	·1619
1° " Ventzke-Soleil	=	·26048
1° " Wild (sugar scale)	=	·1000
1° " Shadow sacchar. (of Laurent and Duboscq)	=	·1619

1° Mitscherlich = 4·635° Soleil-Duboscq.
1° " = 2·879° Soleil-Ventzke.

1° Soleil-Duboscq = ·215° Mitscherlich.
1° " " = ·620° Ventzke-Soleil.
1° " " = 1·619° Wild.
1° " Ventzke = ·346° Mitscherlich.
1° " " = 1·608° Soleil-Duboscq.
1° " " = 2·648° Wild.
1° Wild (sugar scale) = ·618° Soleil-Duboscq.
1° " " = ·384° Soleil-Ventzke.
1° " " = ·133° Mitscherlich.

Equivalence in Circular Degrees.—

Wild (sugar scale) 1° = ·1328 circ. degree D.
Soleil-Duboscq j 1° = ·2167 " " D.
" " j 1° = ·2450 " " j.
Soleil-Ventzke j 1° = ·3455 circ. degree D.
" " j 1° = ·3906 " " j.

Instruments reading angular degrees, such as Wild's, Laurent's and Duboscq's *saccharimètre à pénombre* may be made to give the concentration—i.e. the number of *grm.* of sugar in 100 *cc.* of solution—by the following formula

$$C = \frac{100\,a}{k\,[a]\,D}$$

in which a is the observed angle of rotation, k the length of the observation-tube in decimetres, and $[a]$ D the specific rotatory power of cane-sugar for monochromatic light, which, for most purposes may be placed at 66·4°. When the sp. gr. of the solution operated upon is known, the percentage by weight can be calculated by dividing the value of C obtained as above by the density.

Analysis of Commercial Glucose or Starch-sugar.—The production of this sugar has already been described (see pp. 1914–21). It occurs either as solid and granular powder, or a syrup of the character of honey. As in the case of cane-sugar, the full or complete analysis is attended with considerable difficulty, and it is therefore customary to return only 4 or 5 leading figures, which in most cases are sufficient for commercial purposes. The different processes will first be dealt with separately, and then the way in which they are carried out, and the mode in which the results are returned.

The sp. gr. of dextrose solution differs somewhat from that of cane-sugar containing the same amount of solid matter; Pohl gives the following table :—

Density of Solution.	Per cent. Sugar.	Difference in Density.
1·0072	2	− 8
1·0200	5	− 1
1·0275	7	− 6
1·0406	10	+ 1
1·0480	12	− 7
1·0616	15	+ 0
1·0693	17	− 11
1·0831	20	− 7
1·0909	22	− 20
1·1021	25	− 47

Determination of Dextrose by means of Fermentation.—A standard solution of the sample to be examined is made, and the percentage of dry matter estimated. A weighed quantity of yeast is then added to the solution, and it is submitted to fermentation; after the alcohol and carbonic acid formed have been expelled, the percentage of dry matter is again determined by the difference in weight of the entire apparatus before and after fermentation. The difference between the amounts of dry matter before and after the fermentation shows the amount of sugars in the fermentable form. The process incurs a certain loss, which may and frequently does amount to 5 per cent. of the total fermentable sugars present, because part of these in the course of the vinous fermentation are converted into glycerine, succinic acid, and other bodies, which are fixed at the temperature of boiling water, and consequently remain with the residue.

For instance, 100 *grm.* of glucose or starch-sugar, after dissolving in water, and diluted to 1 *litre*, would have a sp. gr. of about 1·030, and it appears from the table above that this corresponds to a percentage of the dried substance of 7·463; but as the substance has been weighed instead of being measured in *cc.*'s, the true percentage as contained in the solution will be 76·87 per cent. dry substance, and 23·13 per cent. water; ½ *litre* of the solution thus made is taken, and a sufficient quantity of fresh yeast, which is active and in good condition, is added; the whole is then placed in a fermenting apparatus, so that the carbonic acid can escape after drying. After weighing the whole apparatus, it is placed on one side at a proper temperature for about 3 days, weighing at intervals in order to ascertain when the action is complete. The liquid in the flask to which the yeast has been added is then measured, and boiled in order to drive off any residual alcohol, and, after cooling, is made up to its original volume, and returned to the flask. The amount of fermentable sugars is ascertained by the difference between the weight of the entire apparatus before and after fermentation. Thus if 500 *cc.* contained originally dry substance equal to 76·87 per cent. of total matter, and the liquid after fermentation contains the equivalent of only 20·67 of unfermentable matters, the residue of fermentable sugars will be 56·20; adding to this 5 per cent. on the quantity found, say 28·04 per cent., gives 58·24 per cent. as the total amount of fermentable sugars probably present.

The main difficulty in this process is the time which it takes, and the fact that from possible non-activity of the yeast it is essential to make 2 analyses of each sample with yeast obtained from different sources.

The proportions of maltose, dextrine, and glucose in brewing sugars prepared from starch may be determined by the optical method in conjunction with Fehling's test. It is necessary first to determine the specific rotatory power of the sample, which is done by dissolving a known weight of the substance in water, and making up to a certain volume; the solid matter is determined from the sp. gr. of the solution, by dividing by 3·85. This figure is constant, and allows an increase of 3·86 in density for each 1 *grm.* of sugar or other carbohydrate in 100 *cc.* of the liquid. The following example is given by A. H. Allen :—

(*a*) On ignition the sample left 0·63 per cent. of ash.

(*b*) The sp. gr. of a solution of 20 *grm.* of the sample diluted to 100 *cc.* was 1063·32 at 15½° (60° F.). This figure divided by 3·85 gives:—

Total solids	82·23 per cent.
Less ash	0·63 ,, ,,
Carbohydrates	81·60 ,, ,,

(*c*) By Fehling's test, the sample was found to have a reducing power equivalent to 72·6 per cent. of glucose. The reducing power of maltose may be taken as $\frac{62}{100}$ that of glucose.

(*d*) A solution of 20 *grm.* per 100 *cc.* observed in a 2-*decim.* tube caused an angular rotation of + 23·7° for the sodium line D. Hence the value of $[\alpha]$ D for the sample was + 59·25°, thus—

$$[\alpha]_D = \frac{23 \cdot 7}{2 \times \frac{20}{100}} = 59 \cdot 25.$$

The values of $[\alpha]_D$ for dextro-glucose, maltose, and dextrine are respectively + 52°, + 139°, and + 193°, ignoring fractional parts of a degree.

Let $[\alpha]_D$ be the apparent specific rotatory power, K the cupric oxide reducing power of the sample, and g, m, and d the respective amounts of glucose, maltose, and dextrine contained in 1 *grm.* of the sample. Then from the above data the following equations result:—

1. $g + m + d = \cdot 816.$
2. $g + \cdot 62\,m + = \mathrm{K} = \cdot 726.$
3. $52\,g + 139\,m + 193\,d = [\alpha]_D = 59 \cdot 25.$

From these

$$g = \cdot 726 - \cdot 62\,m.$$

$$d + g = \cdot 816 - m.$$
$$d + \cdot 726 - \cdot 62\,m = \cdot 816 - m.$$
$$\text{and } d = \cdot 09 - \cdot 38\,m.$$

Substituting the above values for g and d in equation 3, we get

$$52\,(\cdot 726 - \cdot 62\,m) + 139\,m + 193\,(\cdot 09 - \cdot 38\,m) = 59 \cdot 25.$$

Simplying this,

$$37 \cdot 752 - 32 \cdot 24\,m + 139\,m + 17 \cdot 37 - 73 \cdot 34\,m = 59 \cdot 25.$$

Simplifying again, and transposing, we get

$$33 \cdot 42\,m = 4 \cdot 128,$$

whence

$$m = \cdot 1235.$$

The value of m being found, those of g and d are easily derived from equations 1 and 2. Thus:—

$$g = \cdot 726 - \cdot 62\,(\cdot 1235) = \cdot 726 - \cdot 07657 = \cdot 64943.$$
$$d = \cdot 816 - m - g = \cdot 816 - \cdot 1235 - \cdot 6494 = \cdot 0431.$$

As these values represent the respective weights of glucose, maltose, and dextrine in 1 *grm.* of the sample, the percentages will be 64·94, 12·35, and 4·31, together making up 81·60 per cent.

Determination of Sugar by Fehling solution.—This process alone is incorrect as applied to brewing sugars, because maltose, which is almost invariably present in large quantity, acts upon oxide of copper in a different proportion to that in which true grape-sugar acts; thus, while 100 parts of dextrose throw down 220 parts of suboxide of copper, 100 parts of maltose only reduce 141 parts of suboxide of copper. This test, therefore, is only of relative value.

Rumpf and Heinzerling state that solutions of (1) caustic soda and cupric sulphate at the boiling-point do not act on dextrine entirely free from sugar, which corrects Gerhardt's observation, who asserted that dextrine caused a reduction; (2) solutions of alkaline tartrates and Fehling's solution each act upon dextrine, making the results of the dextrose estimation too high in direct proportion to the length of time the heating is continued. When the reduction is quickly effected, and the heating continues only a few minutes, they have found that the error in the estimation of dextrose in the presence of dextrine in starch-sugars is too small to sensibly affect the results.

Anthon's method depends on the fact that the impurities present in commercial starch-sugar have a greater density than the sugar. The process is somewhat empirical, but is said to give fairly accurate results. A saturated solution of starch-sugar is made by dissolving an excess of sugar in a finely divided state in water. The sp. gr. of the clear solution thus produced is ascertained, and from this the percentage of impurity is calculated according to the following table:—

Density of sat. solution.	Per ct. of impurities.	Density of sat. solution.	Per ct. of impurities.	Density of sat. solution.	Per ct. of impurities.
1·2060	0	1·2350	15	1·2587	30
1·2082	1	1·2368	16	1·2603	31
1·2104	2	1·2386	17	1·2618	32
1·2125	3	1·2404	18	1·2633	33
1·2147	4	1·2422	19	1·2649	34
1·2169	5	1·2440	20	1·2665	35
1·2189	6	1·2456	21	1·2680	36
1·2208	7	1·2473	22	1·2695	37
1·2228	8	1·2489	23	1·2710	38
1·2247	9	1·2506	24	1·2725	39
1·2267	10	1·2522	25	1·2740	40
1·2284	11	1·2535	26	1·2755	41
1·2300	12	1·2548	27	1·2770	42
1·2317	13	1·2561	28	1·2785	43
1·2333	14	1·2574	29		

Water.—This is determined by drying the sample when admixed with dry and well-washed sand, as described under the analysis of molasses (see p. 1946). When solid samples of glucose have to be examined for moisture, the solid matter is first melted in a weighed dish in the water-bath at a gentle heat, and a weighed quantity of sand is stirred in.

Admixture of Starch-sugar with Cane-sugar.—It is stated that raw sugars are sometimes adulterated with starch-sugar, and the following methods have been suggested for the detection of the adulteration. It does not appear that the admixture has ever been common in this country, but in America it is said to be very frequent, and it is quite possible that it may prove profitable, because not only is the price of dextrine far lower than that of raw sugar, but it is somewhat similar in colour, and also shows far higher polariscopic reading, 0·40 per cent. of dextrine corresponding to 1 per cent. of sugar.

If the suspected sugar is mixed with water and absolute alcohol, or with alcohol of 95 per cent., and the sugar is washed with it on the filter, there will in most cases be a white coagulum of dextrine left behind, which is recognized by its appearance. If cane-sugar has been adulterated with starch-sugar, the sample on solution in water generally leaves some particles of glucose, which do not dissolve easily or readily. They are mostly white in colour, and if they are sufficient in quantity, it will be found that, on dissolving them in a larger quantity of water and submitting them to the polariscopic test, the reading is markedly different to that of cane-sugar, and not only so, but it gradually diminishes for some hours after the solution has been made. As the rotatory power of starch-sugar is in excess of that of cane-sugar, samples which are adulterated with any notable proportion of starch-sugar will generally give a reading in excess of that which is due to the cane-sugar present, and in consequence the figures of the analysis will very frequently add up to more than 100 per cent.

Casamajor has recommended the use of methylic alcohol of 50 per cent. strength saturated with starch-sugar, as a solution for the purpose of detecting the admixture of starch-sugar with cane-sugar. The mode of applying this test is to wash the suspected sugar with the saturated solution of starch-sugar in methylic alcohol, which readily dissolves the cane-sugar and other impurities, leaving the starch-sugar insoluble; this method, though of value as a qualitative test, cannot be recommended for quantative work.

Chandler and Ricketts' method is probably the best which has yet been proposed for the detection of starch-sugar in cane-sugar, but it is not readily applicable, and is attended with some degree of difficulty in execution. It depends upon the fact that the rotation of a solution of levulose varies with the temperature, while the rotation of dextrose is constant for all temperatures. As invert sugar consists of a mixture of dextrose and levulose in equal proportions, it follows that there is a certain temperature at which invert sugar has no effect upon the polariscope. Hence if a sample of commercial sugar, whether raw or refined, is inverted and heated to a certain definite temperature, viz. 87·2° (189° F.), the rotation of the levulose is neutralized by the dextrose, and the sample does not produce any rotation. Hence if the tube containing the solution of the sample is placed between the polarizer and the analyzer, and surrounded by a jacket or water-bath in such a way that its temperature can be kept definite at 87·2° (189° F.), the rotatory effect due to the cane-sugar is eliminated, and the rotation which is found by the optical examination is due entirely to glucose or intermediate products present. It is obvious that this method requires a special apparatus, inasmuch as the water-bath must be kept uniformly at a fixed temperature; but it is a decided advantage in detecting the presence of the adulterant if its quantity is at all notable, though it is not of use for detecting the character of that adulterant without the use of additional processes.

Analysis of Animal Charcoal, Char, or Bone-black (see pp. 443–4).—Animal charcoal differs much in character, the difference being dependent partly upon the character of the bones used in making it, viz. whether they are fresh or stale, whether they have been thoroughly freed from membranous matters, and more especially whether they have been boiled so as to separate the fatty matters (see pp. 1448–50), or simply cleared from meat in the ordinary way practised by butchers. The greater part of the animal char used in this country is made here from bones obtained from dealers who buy up the residues from butchers and from house use.

Animal char has a remarkable decolorizing power, not only on sugar, but on other coloured solutions. This power has been known and in many cases used chemically for 60–70 years, but it appears to have been in 1821 that Bussy & Pan first thoroughly investigated its manufacture and modes of action. At first it was customary to use it in a fine powder, in which state it is doubtless more efficient; but after once using in this condition, its power is almost destroyed, and it is incapable of being revivified, whereas Dumont discovered in 1828 that by recalcining char which had been used in the form of grains, it was possible to use it repeatedly without any notable diminution in its decolorizing power.

The manufacture from bones is in this country practically in the hands of some 3 or 4 firms. There is nothing peculiar about the process. Certain volatile products pass over from the retorts, —bone-oil (see p. 1360) and animal pitch, both of which have certain limited commercial uses, and a considerable quantity of gas is given off, which is in one or two cases used to light the factories in which the process is carried on (see p. 1450). The general composition of an average sample of good char is similar to the following. Further on will be pointed out alterations in character which take place as the char is used and revivified.

Carbon	11·00	Sulphate of lime	0·20
Carbonate of lime	8·00	Oxide of iron	0·10
Phosphate of lime and magnesia	80·00	Silica	0·30
Alkaline salts	0·40		

It is probable that the action of charcoal in removing colour is entirely physical. Some soluble colouring matters are absolutely absorbed, but these in most cases are given up again to the washing-water, and are therefore simply removed from the refined sugar to the sugar of inferior grades.

The following analyses, taken from the working of a sugar-refinery, show the absorptive power of char for impurities found in sugar solutions:—

	Raw Liquor.	Filtered Liquor.	Char Washings.
Sugar	93·50	95·30	78·50
Grape-sugar	2·14	2·25	3·23
Organic matter not sugar	3·56	2·00*	11·05
Ash	0·80	0·45†	7·22
	100·00	100·00	100·00

* 43·82 per cent. absorbed. † 43·75 per cent. absorbed.

It is probable that the absorptive power of this bone-black is owing to the presence of carbon in a minutely divided state deposited upon what may be called a framework or skeleton of phosphate of calcium in an extremely porous condition, and hence the lighter the char the better it is likely to act.

The substances taken up by the char divide themselves naturally into 2 or 3 different groups; organic bodies of the albumen class are retained with such great tenacity that even after long washing with hot water they are not removed. Certain inorganic salts, such as carbonate of lime, are also obstinately retained, while other soluble substances which are taken up, such as gums and colouring matters, and inorganic bases combined with organic acids, comparatively readily wash out from it.

Walkhoff, many years ago, working with weak solutions of potash and soda salts, arrived at the following results as to the absorptive power of char on the salts mentioned:—

	Per cent. absorbed.		Per cent. absorbed.
Potassium hydrate, at 60° (140° F.)	13·5	Sodium carbonate	24·0
„ „ at 15° (59° F.)	16·6	„ „ at 60° (140° F.)	18·3
„ carbonate	25·0	„ phosphate	32·3
„ phosphate	30·7	„ „	28·0
„ nitrate	6·5	„ nitrate	5·0
„ chloride	3·0	„ sulphate	20·4
„ „	1·3	Magnesium sulphate	49·0
„ citrate	12·2	Sodium chloride	1·0
„ sulphate	22·4		

The character of animal char differs greatly; that of thoroughly good quality is of black colour, and is entirely free from the appearance of incipient fusion or glazing on the surface. If this glazing is visible, it indicates a very inferior quality in the sample. The charcoal should not contain any undue proportion of white or grey particles, which result from excessive burning or access of air during the process. It should be tolerably uniform in size, according to the sized grain at which it is bought, and hard enough to resist the necessary handling to which it must be subjected.

The process of revivifying (see pp. 1923–6), consists in washing the char with hot water, which removes the traces of sugar which are left, and occasionally, though not always, washing it with dilute acids, so as to remove any excess of carbonate of lime which may be present in it; and after this washing or washings, calcining it in a closed retort in a similar way to that in which it was first calcined. If the washing is not carried far enough, the ignition of the residual sugar produces an increased amount of carbon, and so injures the quality of the revivified char. The heat employed in the revivification must be sufficient to perfectly char any organic matter which is present; the consequence is that in this burning process an additional quantity of inert non-nitrogenous carbon is deposited in the body of the grain, which not only makes the char itself more dense, but decreases the amount of cellular particles, and diminishes its decolorizing power. It is generally possible to distinguish old char from new char by the proportion of carbon present. The following table (from Tucker) gives a series of analyses of char which had been used in a refinery for different periods :—

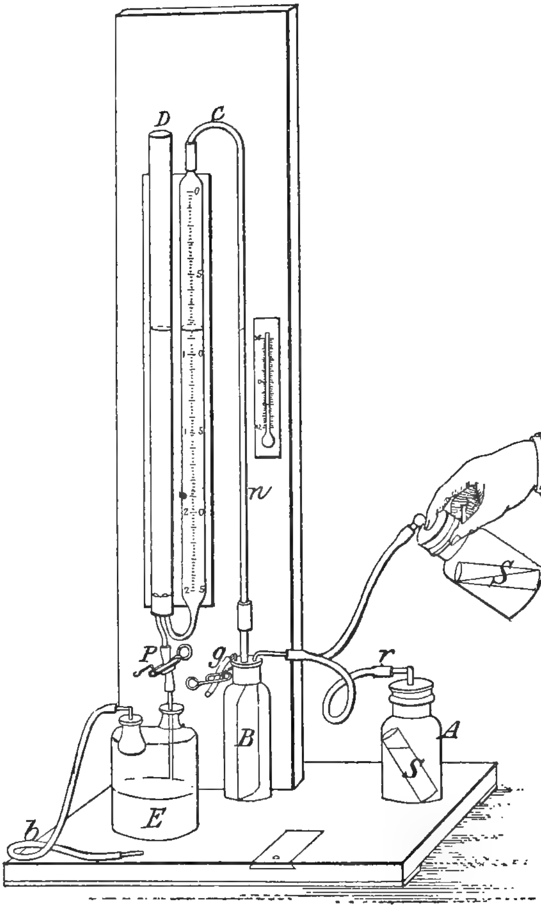
	Average of new black.	April 4.	May 1.	May 22.	June 3.	July 12.	Aug. 7.	Sept. 20.	Oct. 15.	Nov. 6.	Dec. 1.	Dec. 8.	Jan. 8, 1878.
Moisture	3·37	0·68	..	..	..	..	..	..	..	..	..	..	..
Carbon	8·05	7·65	8·05	8·38	8·74	9·62	9·15	9·44	9·59	9·89	10·07	10·07	10·01
Carbonate of lime	6·71	5·03	5·47	6·11	5·40	4·86	4·34	4·21	4·33	4·12	4·08	4·16	4·14
Iron	0·18	0·21	0·21	0·23	0·19	0·24	0·20	0·25	0·32	0·34	0·32	0·33	0·36
Insoluble matter	0·43	0·45	0·46	0·58	0·26	0·48	0·44	0·38	0·34	0·44	0·33	0·63	0·42
Sulphate of lime	..	..	0·35	..	..	0·49	0·34	0·44	..	0·49	0·31	..	..
Sulphide of calcium	..	..	..	..	..	..	..	..	..	..	..	..	0·41
Lb. per cub. ft.	42·70	49·90	51·30	52·90	52·90	53·90	51·90	56·40	55·50	55·30	58·80	61·70	58·70
Decolorizing power—per cent. of colour absorbed from a sugar solution	58·20	..	..	54·00	52·70	..	52·30	51·80	51·80	43·50	47·60	48·00	..

Nitrogen in a state of combination is present in almost all good char. It is difficult to understand why it should be so important in connection with the value of the char for purifying purposes; still it is seldom that char which contains a very small proportion of nitrogenous matter will be classed as efficient or useful for practical work.

Analysis of Animal Charcoal.—For determination of water, dry for 3–4 hours until the sample ceases to lose weight. For determination of carbon, weigh 4 or 5 *grm.* of the finely powdered char, transfer to a flask, and boil with about 70 *cc.* of dilute hydrochloric acid (1 of acid to 1 of water); dilute with hot distilled water, settle, and decant on to a tared filter; wash the sediment 2 or 3 times with very dilute acid, passing the washings through the same filter, and finally wash the carbon in the usual way on to the filter. After washing on the filter until the washings are no longer acid, dry the filter at 100° (212° F.), until it ceases to lose weight, and weigh; then transfer the filter to a weighed crucible, ignite, and reweigh. The loss of weight is the amount of carbon, plus the volatile matter and the filter itself; while the residue left in the crucible is the fixed ash of the filter, plus the insoluble ash of the char.

The determination of carbonate of lime is very frequently necessary in dealing with char; the instrument usually adopted for this in sugar-refineries is Scheibler's calcimeter. This apparatus is not very accurate, but the results are to be relied upon within 0·2–0·3 per cent., and therefore sufficiently near for ordinary work in refineries. The apparatus is shown in Fig. 1425, and consists of the following parts. The evolution-flask, in which the sample of char is treated with hydrochloric acid, is placed in the glass tube S. This flask is shown in two positions, one in the stand on the base-board, and the other when lifted in the hand during the process of analysis. The glass stopper of the flask A is perforated, and carries a tube to which is joined an indiarubber tube *r*, connecting the flask A with the bottle B. This bottle B has an indiarubber stopper with 3 holes, each fitted with a tube; the tube joined to *r* stands a short distance inside the vessel B, and the neck of it has fastened to it a thin indiarubber bag or bladder, similar to those commonly used for making toy balls. Tube *g* has a piece of indiarubber tubing connected with it, which is closed by a pinchcock while the estimation is being made, and serves to bring the vessel B into communication with the air when necessary. The glass tube *n* connects the interior of the vessel B with the top of the graduated tube C, which is divided into 25 equal parts (about 4 *cc.* each), each division being subdivided into tenths; the lower part of this is in communication with the straight tube D, which is open at the upper end, and closed at the lower end by an indiarubber cork pierced with two holes, through one of which is passed a pipe leading from the graduated tube C and through the other tube to the two-necked Wolff-bottle E, the action between the two being regulated by the pinchcock P. E is a reservoir for water, and C D are filled from it by blowing through the flexible tube *b*, the pinchcock P preventing the reflux of the water. The whole apparatus excepting the bottles is fastened to an upright board, and the bottles are supported when necessary on a shelf attached to the board.

1425.



The test of a sample of char is carried out in the following way. By blowing through the flexible tube *b*, the liquid is forced into the tubes C D until it reaches a little above the zero point in C, when it is allowed to fall by opening P until the level in C is at zero. The water must not be allowed to flow into B, as if this were done it would be necessary to take the apparatus to pieces to dry B. A sample of the char is pulverized, and the normal weight, viz. 1·702 *grm.* is placed in the flask A, carefully dried before use, and the small test-tube S, filled with dilute hydrochloric acid of sp. gr. 1·120, is cautiously placed in the flask, so that none of the acid shall be spilt. The stopper, which should be well greased, is now placed in A, and connection made with B by means of the tube *r*. If the levels of the liquids in D and C are unequal, the cock *g* must be opened for a few seconds to allow them to recover their normal level. The vessel A is now lifted from the shelf into the upper position shown, so that the acid may flow out of the tube and come into contact with the char; the flask being gently shaken causes the acid to mix thoroughly with the sample. The gas evolved escapes into the indiarubber bag contained in the flask B, which forces air up the capillary tube *n*, and depresses the column of water in the graduated tube C. The stopcock P is now cautiously opened, so as to let the water in the tube D flow out, keeping the levels of water in the two tubes as nearly as possible alike. When all the gas has been given off, and the level of the liquid in the tube C becomes stationary, the liquid in the two tubes is brought to the same level by opening the pinchcock P, and the volume and temperature are read off. The following table gives the percentage of carbonate of lime found corresponding to each division as read off on this instrument when the normal weight has been used, with the proper corrections for temperature (in degrees C.). The use of this determination in practical work is for the purpose of enabling a refiner to remove the carbonate of lime by washing with dilute acid. It may be assumed that 7 per cent. is the normal amount of carbonate of lime contained in animal char, and this table gives the quantities of commercial hydrochloric acid containing 33·3 of real acid necessary for the purpose of removing any excess of carbonate of lime which may be found.

TABLE FOR CALCULATING THE PERCENTAGE OF CARBONATE OF LIME FROM THE VOLUME OF CARBONIC ACID: FOR USE WITH SCHEIBLER'S CALCIMETER.

Volume read.	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
1	·80	·80	·79	·79	·79	·78	·78	·77	·77	·77	·76	·76	·76	·75	·75	·74	·74	·73	·73
2	1·88	1·87	1·86	1·86	1·85	1·84	1·83	1·82	1·81	1·80	1·79	1·79	1·78	1·77	1·76	1·75	1·74	1·73	1·72
3	2·95	2·94	2·92	2·91	2·90	2·89	2·87	2·86	2·85	2·83	2·82	2·80	2·79	2·77	2·76	2·74	2·73	2·72	2·71
4	4·01	4·00	3·98	3·96	3·94	3·93	3·91	3·89	3·87	3·85	3·83	3·81	3·79	3·77	3·75	3·73	3·71	3·70	3·68
5	5·07	5·05	5·03	5·00	4·98	4·96	4·93	4·91	4·87	4·86	4·84	4·81	4·79	4·76	4·74	4·71	4·69	4·67	4·65
6	6·11	6·09	6·06	6·03	6·01	5·98	5·95	5·92	5·89	5·86	5·83	5·81	5·78	5·75	5·71	5·68	5·65	5·63	5·61
7	7·14	7·12	7·09	7·06	7·02	6·99	6·96	6·92	6·89	6·86	6·82	6·79	6·75	6·72	6·68	6·65	6·61	6·58	6·56
8	8·17	8·14	8·11	8·07	8·03	8·00	7·96	7·92	7·88	7·84	7·80	7·76	7·72	7·68	7·64	7·59	7·55	7·53	7·49
9	9·19	9·16	9·12	9·07	9·03	8·99	8·95	8·90	8·86	8·82	8·77	8·73	8·68	8·64	8·59	8·55	8·50	8·46	8·42
10	10·20	10·16	10·12	10·07	10·02	9·98	9·93	9·88	9·83	9·79	9·73	9·68	9·63	9·58	9·53	9·48	9·43	9·39	9·34
11	11·20	11·15	11·10	11·05	11·00	10·95	10·89	10·84	10·79	10·74	10·68	10·63	10·57	10·52	10·46	10·41	10·35	10·30	10·25
12	12·20	12·15	12·09	12·03	11·99	11·92	11·87	11·81	11·75	11·69	11·64	11·58	11·52	11·46	11·40	11·33	11·27	11·22	11·16
13	13·20	13·14	13·08	13·02	12·96	12·90	12·84	12·78	12·72	12·65	12·59	12·53	12·46	12·40	12·33	12·26	12·20	12·14	12·07
14	14·20	14·14	14·07	14·01	13·94	13·88	13·81	13·75	13·68	13·61	13·54	13·48	13·41	13·34	13·26	13·19	13·12	13·05	12 99
15	15·20	15·13	15·06	14·99	14·92	14·85	14·78	14·71	14·64	14·57	14·50	14·42	14·35	14·27	14·20	14·12	14·04	13·97	13·90
16	16·20	16·13	16·05	15·98	15·91	15·83	15·76	15·68	15·61	15·53	15·45	15·37	15·29	15·21	15·13	15·05	14·97	14·89	14·81
17	17·20	17·12	17·04	16·97	16·89	16·81	16·73	16·66	16·59	16·49	16·41	16·32	16·24	16·15	16·07	15·98	15·89	15·81	15·72
18	18·20	18·12	18·03	17·95	17·87	17·79	17·70	17·62	17·53	17·45	17·36	17·27	17·18	17·09	17·00	16·91	16·82	16·73	16·63
19	19·20	19·11	19·03	18·94	18·85	18·76	18·67	18·59	18·50	18·40	18·31	18·22	18·13	18·03	17·94	17·84	17·74	17·64	17·55
20	20·20	20·11	20·02	19·93	19·83	19·74	19·65	19·55	19·46	19·36	19·27	19·17	19·07	18·97	18·87	18·77	18·66	18·56	18·46
21	21·20	21·10	21·01	20·91	20·81	20·72	20·62	20·52	20·42	20·32	20·22	20·12	20·01	19·91	19·80	19·70	19·59	19·48	19·37
22	22·20	22·10	22·00	21·90	21·80	21·70	21·69	21·49	21·39	21·28	21·17	21·0	20·96	20·85	20·74	20·63	20·51	20·40	20·28
23	23·20	23·09	22·99	22·88	22·78	22·67	22·56	22·46	22·36	22·24	22·13	22·02	21·90	21·79	21·67	21·55	21·44	21·31	21·20
24	24·20	24·09	23·98	23·87	23·76	23·65	23·54	23·43	23·31	23·20	23·08	22·97	22·85	22·73	22·61	22·48	22·36	22·23	22·11
25	25·20	25·08	24·97	24·86	24·74	24·63	24·51	24·39	24·28	24·16	24·04	23·91	23·79	23·67	23·54	23·41	23·28	23·15	23·02

For determination of sulphate of lime, 10 *grm.* of the finely pulverized sample are placed in a porcelain basin with 80 *cc.* of dilute hydrochloric acid, and heated for 1 hour on the water-bath; the residue is washed into a 250-*cc.* flask, diluted to the mark, and filtered; 200 *cc.* of the clear filtrate, corresponding to 8 *grm.* of the original substance, are precipitated with chloride of barium, heated, and the precipitated barium sulphate is filtered off, the residue being washed on the filter with hot water slightly acidified with hydrochloric acid; the filtrate is dried, precipitated, and ignited in the usual way, and the residue of sulphate of barium × ·582 = calcium sulphate. For determining calcium sulphide, 10 *grm.* of the powdered sample are weighed, transferred to a porcelain dish, and treated on the water-bath with 20 *cc.* of fuming nitric acid, which must be added cautiously, to prevent too violent effervescence. After ½ hour, 20 *cc.* more of fuming nitric acid and 20 *cc.* of pure hydrochloric acid are added, and the whole is stirred for 20 minutes longer. The mixture is now evaporated to dryness, and the contents of the dish are washed into a 250-*cc.* flask; the liquid when cooled is diluted to the mark, and filtered; 200 *cc.* of the filtrate, corresponding to 8 *grm.* of char, are precipitated with barium chloride, and the amount of barium sulphate precipitate is determined as before; the difference between the weight of the barium sulphate in the two cases corresponds to the amount of calcic sulphide present, and may be calculated thus,—barium sulphide × ·309 = calcic sulphide.

Calcic phosphate may be estimated by cautious ignition of about 1 *grm.* of the finely powdered char, dissolving the residue in dilute nitric acid, and precipitating by magnesia solution, as in the ordinary determination of phosphates. Where accuracy is necessary, the precipitate should be redissolved after washing with water in dilute hydrochloric acid, and reprecipitating with ammonia.

Determination of iron is seldom necessary, and a qualitative test is generally sufficient, the reactions obtained in this way being enough to show whether iron is present in sufficient quantity. The soluble matters are determined by boiling a quantity (preferably not less than 50 *grm.*) of the roughly powdered char with water, decanting, boiling again, making up the liquid to a known volume, and evaporating half of it. The weight of the dried residue is the total soluble matter, and this, if cautiously ignited at a low red heat, leaves the soluble mineral matter, which can then be weighed. The difference is the organic soluble matter. In the other half of this solution, the sugar and glucose should be determined by means of Fehling solution.

Two specific-gravity determinations are required in this case, one of the apparent sp. gr., and the other of actual sp. gr. The first is obtained by filling a flask of known capacity (say ½ *litre*) with the sample of char, shaking it gently so as to ensure its being properly packed, and filling up to the mark. The weight of the contents, after deducting the tare of the flask, as compared with the weight of the same flask in distilled water, gives the apparent sp. gr. of the char. The actual or real sp. gr. is obtained by weighing 100 *grm.* of the char in a tared 200-*cc.* flask, partially filling it with distilled water, boiling for some minutes to free the char from air, then cooling, filling up to the mark, and weighing. The amount of water displaced by the char is obtained by comparison with the actual contents of the flask, and gives the real sp. gr. of the char.

The decolorizing power of char on sugar is determined by taking solutions of dark coloured sugar, and diluting them until the tint is such that they are capable of being estimated in one of the numerous forms of colorimeters now in use. Duboscq's colorimeter, which is perhaps most generally used, consists of two glass cylinders side by side, one of which is destined to receive the solution to be examined, and the other the standard liquor. Two small tubes capable of being moved up and down through the corks which close the tops of the larger tubes are shut at the bottom by clear glass plates, and passed through the corks. Below the larger tubes, is a mirror to reflect the light in a vertical direction through them, and above them are two double-reflecting prisms, which bring the images of the two smaller tubes side by side into the luminous field of a small Galilean telescope. In this case, the samples are worked against a standard solution made by dissolving caramel in water. Practically the test is best made by shaking a weighed quantity of the charcoal to be tested and a sugar solution of known quality, and comparing with another standard sample of charcoal weighed in equal proportions to the same sugar solution, then examining the relative decolorizing powers by any of the known colorimeters.

Milk-sugar, Characters and Analysis.—Milk-sugar, lactose, or lactine ($C_{12}H_{22}O_{11}$), an isomer of cane-sugar, is prepared from milk, which contains about 4 per cent., in the manner described on pp. 1903–4; the product thus obtained can be further purified by passing its aqueous solution through animal charcoal, evaporating the water, and recrystallizing. Milk-sugar crystallizes in hemihedral trimetric prisms, of the composition $C_{12}H_{22}O_{11}+H_2O$; by heating to 130° (266° F.), the crystals melt and lose one atom of water; the anhydrous milk-sugar, which remains in the form of a liquid mass, solidifies into small crystals on cooling. Milk-sugar dissolves readily in weak acetic acid, and crystallizes again unaltered; it is insoluble in absolute alcohol and ether, soluble in 5–6 parts of cold and $2\frac{1}{2}$ parts of boiling water. A saturated solution in water has a density of 1·055, and contains 14·55 per cent. crystallized milk-sugar; when concentrated, this solution deposits crystals so soon as it has attained a density of 1·062; it then contains 21·64 per cent. milk-sugar. This change in solubility is accounted for by Hesse on the supposition that the size of the molecules of the two modifications of milk-sugar stand to one another as 3 to 2, so that by boiling, the β variety is produced, the molecules of which occupy $\frac{1}{3}$ less space. The specific rotatory power for the α variety is $[\alpha]_D + 80°$, and for β variety 52·7°. Milk-sugar is charred by warm concentrated sulphuric acid; heated with the diluted acid, its optical rotatory power is increased, galactose ($C_6H_{12}O_6$) being formed; according to more recent researches, two sugars are formed (corresponding with dextrose and lævulose from cane-sugar), both fermentable, but differing in their solubility in alcohol, and in their specific rotatory power, though both are dextro-rotatory. The specific rotatory powers for the two are given as—

$[\alpha]_D$ .. .. 92·83° | $[\alpha]_D$ .. .. 62·63°

Both are birotatory.

Milk-sugar ferments with yeast, but more slowly than grape-sugar or dextrose, yielding alcohol and carbonic acid; with most of the bases, it forms well defined compounds; it does not combine with sodium chloride. There are two calcium compounds of it, one soluble and containing equal numbers of molecules of lime and sugar, the other insoluble and containing a larger proportion of lime.

To determine the amount of milk-sugar present in milk, it is necessary first to remove the fat and caseine: the former obscures the liquid to such an extent that it is not possible to obtain accurate readings if the determination is made by polariscope, nor accurate results if by means of Fehling solution; and the caseine has a considerable left-handed rotation. Owing to the birotation which is exhibited by milk-sugar, it is undesirable to employ the optical method if it can be avoided, and the Fehling process is the more reliable of the two.

The mode in which the estimation is carried out is similar to that used for glucose and invert sugar (see p. 1963), except that the solutions have to be heated or boiled somewhat longer, as the action does not take place so rapidly, though the volumetric or gravimetric methods may be used.

It is preferable to employ a dilute solution of milk-sugar, say 0·1 per cent.; to a measured quantity while boiling, is added excess of boiling Fehling solution; the mixture is boiled for a few minutes, and the precipitate is allowed to settle, filtered, and treated as described on p. 1945: 1 equivalent of milk-sugar reduces 7 of cupric oxide.

Composition of Commercial Sugars.—The following are analyses of characteristic raw and refined commercial sugars made in 1881, by Wigner and Harland for the Food Collection at Bethnal Green Museum:—

Raw Sugars.	No.	Crystallizable Sugar.	Uncrystallizable Sugar.	Ash.	Moisture.	Unknown Organic Matters.
Dominica	5930	88·30	3·36	1·22	4·95	2·17
Grenada	5931	87·00	3·61	·90	4·74	3·75
Guatemala	5932	82·40	5·48	·78	6·30	5·04
Havana	5933	91·90	2·98	·72	1·70	2·70
Jamaica	5936	90·40	3·47	·36	4·22	1·55
Porto Rico	5940	87·50	4·84	·81	4·25	2·60
St. Kitts	5941	88·70	4·18	1·02	2·79	3·21
St. Lucia	5942	84·20	5·38	1·32	2·39	6·71
St. Vincent	5943	92·50	3·61	·63	·81	2·45
Surinam	5947	86·80	4·31	2·28	5·27	1·34
Trinidad	5948	88·00	5·14	·96	4·23	1·67
Grainy Peruvian	5949	94·80	1·44	·60	1·02	2·14
Cheney	5951	87·40	3·18	1·33	2·74	5·35
China	5952	72·50	9·19	1·80	6·76	9·75
Benares	5957	94·50	2·6	1·50	·98	·39
E. I. Date	5960	86·00	2·19	2·88	6·04	2·89
White Java	5961	99·20	·20	·20	·40	trace
Unclayed Manilla	5962	82·00	6·79	2·00	5·97	3·24
Refined Sugars—						
Tate's crystals	5973	99·90	none	trace	trace	none
French pulverized	5983	99·70	trace	·10	·20	"
Martineau	5984	99·70	"	·10	·20	"
Duncan's granulated	5985	99·80	"	·10	·10	"
Say's loaves	5987	99·80	"	·10	·10	"
Martineau's tablets	5988	99·80	none	·10	·10	"
Boyd titlers	5989	99·70	trace	·10	·20	"
Beet-sugar loaf	6074	99·60	"	·15	·25	"
" crystals	6076	99·90	none	trace	trace	"

G. W. W. & R. H. H.

PRODUCTION AND COMMERCE.—*Abyssinia.*—Our imports thence of unrefined sugar were 1880 cwt., 2430*l.*, in 1877.

Argentine Republic.—The provinces of Tucuman and Santiago, in the central part of the Republic, have lately imported much English machinery for sugar-making. The annual crop has a value of about 150,000*l.*

Australia.—The area occupied by sugar-cane in 1879 was 17,652 acres in Queensland, and 7778 in New South Wales. S. Australia is also entering on the culture. Queensland exported 5500 tons of sugar in 1880, the total crop amounting to over 20,000 tons. We imported 4525 cwt. of molasses, value 1628*l.*, from New South Wales in 1880.

Austro-Hungary.—The beet-crop in 1880 was 32,968,757 met. centners (of 110¼ lb.). The exports were:—Refined sugar: 675,000 met. cent.; raw: 1,624,000 met. cent.

Belgium.—Our imports therefrom of refined and candy were 35,775 cwt., 62,739*l.*, in 1877; 108,313 cwt., 155,340*l.*, in 1880. Unrefined: 578,931 cwt., 621,945*l.*, in 1876; 493,349 cwt., 540,241*l.*, in 1880.

Borneo.—In 1863, 200 acres were planted with cane; and in 1865, 10,000 dol. worth of sugar was exported.

Bourbon.—Cane acreage, 43,672 *hectares* (of 2½ acres) in 1874; exports to France in same year, 8,876,298 *kilo.* We imported thence 14,750 cwt. unrefined sugar, 16,880*l.*, in 1877.

Brazil.—The sugar-cane grows throughout Brazil, but chiefly in the provinces of Rio Janeiro, Sao Paulo, Bahia, Pernambuco, Parahiba, Ceará, Alagoas, and Rio Grande del Norte. Central factories are being widely established. The exports were:—From Maceio, in 1880, 366,443 bags (of 170 lb.), chiefly to the Channel and New York. Aracaju: 32,608,750 *kilo.* (of 2·2 lb.) in 1877, 19,422,075 in 1878, 15,871,240 in 1879; in the last year, 3,162,792 *kilo.* were white sugar, value 64,076*l.*, and 12,708,450 *kilo.* brown, value 177,968*l.* Pernambuco: 1626 tons, 17,670*l.*, in 1871; 10,278 tons, 117,860*l.*, in 1877; 9920 tons, 106,610*l.*, in 1880. Ceará: 48,846 bags in 1876, 560 in 1878. Total Brazilian exports: 206,682,123 *kilo.* in 1874–5; 146,857,810 in 1878–9. Our imports from Brazil were:—Unrefined: 1,860,707 cwt., 1,692,088*l.*, in 1879; 1,484,924 cwt., 1,512,709*l.*, in 1880.

Canada.—Both beet and sorghum growing are commencing to attract attention in Canada, where the climate is found to be well adapted to sugar raising. As yet there are no exports.

Cape Colony.—Our imports thence of unrefined sugar were 13,513 cwt., 13,352*l.*, in 1876; 45,277 cwt., 47,486*l.*, in 1880.

Cayenne.—The cane acreage in 1874 was 235 *hectares* (of 2½ acres). The annual production has fallen to about 250,000 *kilo.* (of 2·2 lb.).

Central America.—Our imports thence of unrefined sugar were 15,552 cwt., 18,228*l.*, in 1877; 1738 cwt., 1737*l.*, in 1880.

Chili.—Our imports thence of unrefined sugar were 29,590 cwt., 29,672*l.*, in 1876; 79,658 cwt., 90,766*l.*, in 1880.

China.—The total annual production is estimated at 200,000 tons, mainly from cane. There are two refineries in Hong Kong, and a third at Swatow, drawing supplies from China, Cochin China, the Philippines, Straits Settlements, and Java. Our imports of unrefined sugar from China, including Hong Kong and Macao, were 1,115,758 cwt., 1,150,653*l.*, in 1877; 359,821 cwt., 301,307*l.*, in 1880.

Colombia.—The sugar-cane is grown in Carthagena province to a limited extent. Our imports thence were:—Unrefined: 31,772 cwt., 31,567*l.*, in 1876; 17,919 cwt., 20,277*l.*, in 1880.

Danish W. Indies.—Our imports of raw sugar thence were 3 cwt., 3*l.*, in 1876, and 52,113 cwt., 63,859*l.*, in 1880.

Egypt.—Nearly 100,000 acres are under cane. The values of the exports in 1880 were:—320,554*l.* to Great Britain, 284,273*l.* France, 123,542*l.* Italy, 35,465*l.* Turkey, 700*l.* Greece, 22*l.* Austria, 11,196*l.* other countries; total, 775,752*l.* Our imports thence were:—Refined and candy: 8840 cwt., 11,340*l.*, in 1876; 59,474 cwt., 78,465*l.*, in 1880; unrefined: 220,459 cwt., 204,220*l.*, in 1876; 195,217 cwt., 229,381*l.*, in 1880; molasses: 1212 cwt., 360*l.*, in 1879; 30,057 cwt., 9408*l.*, in 1880.

France.—The annual production of beet-sugar is about 400 million *kilo.* (of 2·2 lb.), requiring 8 million tons of beet. The imports of sugar are about 180 million *kilo.*; the local consumption, 270 million. In 1875–6, 525 factories made 449 million *kilo.*; in 1879–80, 509 made 278 million; in 1880–1, the make was 320 million. The exports were:—From Calais: raw French, 298,922 *kilo.* in 1879, 11,614 in 1880; refined, not French, 24 in 1879, 108,709 in 1880; Dunkirk: sugar, 15,689,947 *kilo.* in 1879, 15,014,370 in 1880; glucose: 2,722,048 in 1879, 70,473 in 1880; all to England; Nantes: in 1880, 8,402,800 *kilo.* refined sugar, to England, Spain, Turkey, Chili, and Switzerland; and 236,274 *kilo.* treacle to Norway. Our imports from France were: Refined and candy: 2,313,676 *kilo.*, 3,391,378*l.*, in 1878; 1,586,416 *kilo.*, 2,342,912*l.*, in 1880; unrefined: 698,201 *kilo.*, 707,929*l.*, in 1876; 115,298 *kilo.*, 136,089*l.*, in 1880.

Germany.—The 1879–80 beet crop gave the following result:—Factories working, 328: 291 by diffusion, 28 by presses, 8 by maceration, 1 by centrifugal; beet used, 4,628,748 tons; yield of washed and topped roots, 25·2 *kilo.* (of 2·2 lb.) per *hectare* (of 2½ acres); yield of *masse-cuite*, 11·54 per cent.; yield from 100 *kilo.* of *masse-cuite*, 73·85 *kilo.* sugar, and 23·70 molasses; 100 *kilo.* of sugar required 1174 *kilo.* of roots. Our imports from Germany were:—Refined and candy: 30,976 cwt., 48,562*l.*, in 1876; 244,645 cwt., 339,969*l.*, in 1880; unrefined: 1,516,233 cwt., 1,688,786*l.*, in 1876; 4,384,268 cwt., 4,728,916*l.*, in 1880. The receipts of raw sugar at Hamburg were:—

Whence received.	1876.	1877.	1878.	1879.	1880.
	cwt.	cwt.	cwt.	cwt.	cwt.
Interior of Germany ..	1,500,597	1,548,745	1,977,488	2,467,966	4,379,716
Brazil	7*	22,181	566	19,237	Seawards 127,946
Porto Rico	5*	15,881	15,778	5,111	
Great Britain	12,146	16,928	7,078	9,649	
Cuba	4,822	..*	..*	..*	
Holland (by sea)	12,320	29,666	9,739	3,185	
Dutch East Indies ..	23,584	67,436	32,042	53,902	
Other countries	14,500	9,878	3,042	4,412	
Total	1,567,981	1,710,715	2,045,733	2,563,462	4,507,662

* In these years a total failure of the crop occurred.

Guatemala.—The exports of good sugar in 1879 were:—52,500 quintals (of 110 lb.) to England, 68,550 to California, 10,000 to S. America, 3000 to Central American States. Of common sugar, in the same year:—49,650 to England, 38,100 to New York, 53,700 to California, 19,900 to Central American States. Totals, 134,050 quintals, 13,405 dol. (of 4*s.* 2*d.*); and 161,350 quintals, 5647 dol. Escuintla is the centre of the principal sugar-growing district.

Guiana.—The cane acreage in May 1881 was 40,877 acres in Demerara, 18,286 in Essequibo, 15,294 in Berbice. The exports in 1880 were :—From Demerara, 69,682 hhds., 8228 tierces, 2321 bar. sugar; 16,976 casks molasses. Berbice: 1247 hhds., 37 tierces, 381 bar., 34,895 bags sugar; 25 puns. molasses. Our imports thence were :—Refined: 11 cwt., 19*l.*, in 1877; 16,338 cwt., 22,851*l.*, in 1880; unrefined: 1,569,893 cwt., 1,920,769*l.*, in 1876; 1,327,084 cwt., 1,778,481*l.*, in 1880; molasses: 2034 cwt., 765*l.*, in 1876; 20,888 cwt., 10,189*l.*, in 1880.

Holland.—Five years' commerce in raw and refined sugars, in Netherlands lb. (of 2·2 lb.), was :—

	1875.	1876.	1877.	1878.	1879.
	N. lb.	N. lb.	N. lb.	N. lb.	N lb.
Imports, raw	62,700,000	69,900,000	58,500,000	59,000,000	43,000,000
Exports „	17,556,000	29,000,000	16,000,000	18,800,000	21,300,000
„ refined	76,778,400	74,800,000	62,500,000	64,400,000	63,800,000

Of 45,852,681 N. lb. of refined exported from Amsterdam in 1879, 32,639,733 N. lb. came to England. Our total imports from Holland of refined and candy were 647,605 cwt., 929,985*l.*, in 1876; 876,471 cwt., 1,275,717*l.*, in 1880. Unrefined: 298,440 cwt., 316,705*l.*, in 1876; 205,601 cwt., 223,900*l.*, in 1880.

Honduras.—Cane-sugar is easily produced here at 10*l.* a ton, and the rate of 2 tons per acre. Canes ratoon well for 10–12 and even 20 years. The area under cane is over 10,000 acres. The exports were 177½ tons in 1862, 2203 in 1872. Our imports thence of unrefined were 36,656 cwt., 32,078*l.*, in 1876; 18,207 cwt., 18,273*l.*, in 1880.

India.—The area under sugar-cane in British India is over 1½ million acres, chiefly in the N.-W. Provinces. The exports were 1,144,467 cwt., 999,503*l.*, in 1877; 368,566 cwt., 350,425*l.*, in 1879. Our imports of unrefined sugar were :—Madras: 150,484 cwt., 112,411*l.*, in 1879; 487,048 cwt., 349,803*l.*, in 1880. Bengal and Burma: 558,139 cwt., 646,844*l.*, in 1877; 25,851 cwt., 27,113*l.*, in 1880.

Java.—Cane acreage, about 70,000 acres. Crop of 1879, 3,933,000 *piculs* (of 135½ lb.); 1880, 3,294,500. Exports of 1879 crop:—2,356 530 *piculs* to Channel for orders, 329,053 Holland, 328,967 Australia, 284,458 America, 161,971 France, 35,975 Persian Gulf, 35,125 Singapore, 19,088 Lisbon for orders, 12,133 China, 10,403 Cadiz for orders, 2164 Siam; total, 3,575,867. Our imports from Java were :—Unrefined: 1,215,800 cwt., 1,400,981*l.*, in 1876; 1,763,522 cwt., 2,226,225*l.*, in 1880.

Mauritius.—In 1876, the export of home-made sugar was 115,801 tons; in 1877, 136,292; in 1878, 128,329. Our imports thence of unrefined sugar were 1,205,354 cwt., 1,747,147*l.*, in 1877; 120,516 cwt., 137,021*l.*, in 1880.

Mexico.—Our imports thence of unrefined sugar were 30,560 cwt., 32,532*l.*, in 1876; 94,879 cwt., 98,113*l.*, in 1880.

Natal.—The 1881 crop was estimated to produce 15,000 tons of sugar. Plant canes give 2½ tons sugar per acre, and 1st and 2nd ratoons, 1½ tons, on the average. Our imports thence of unrefined sugar were 22,189 cwt., 22,027*l.*, in 1876; 31,405 cwt., 29,234*l.*, in 1880.

New Zealand.—Beet has been grown in the Waikato district yielding 15 per cent. of sugar, and a German company are erecting a factory to make 10,000 tons of sugar per annum.

Pacific Islands.—The Sandwich Islands produce yearly about 30 million lb. of sugar, and 500,000 gal. molasses. Fiji had 1838 acres under cane in 1879. Tahiti has about 300 acres under cane.

Peru.—Annual production, about 100,000 tons of cane-sugar. The crop is remarkably certain. The exports were 60,000 tons in 1875, over 70,000 in 1876. Our imports of unrefined sugar thence were 1,000,987 cwt., 1,128,062*l.*, in 1880.

Philippines.—The sugar-cane is grown in Negros, Panay, Cebu, Luzon, and nearly every part of the Archipelago; the best sugar is from Pampanga and La Laguna, the worst from Taal or Batangas. The 1880 exports were 1,581 188 *piculs* (of 139½ lb.) from Manilla, 1,004,394 from Yloilo, 321,574 from Cebu; total, 2,907,156 *piculs,* 2,620,000*l.* Our imports thence of unrefined sugar were 1,027,365 cwt., 894,006*l.*, in 1876; 1,175,140 cwt., 983,590*l.*, in 1880.

San Domingo.—Exports in 1880:—Sugar: 3138 tons to the United States, 134 W. Indies, 25 Great Britain; total, 3297; molasses: 172,440 gal. United States. The actual total exports were at least 5000 tons, and cane-culture is spreading.

Servia.—A Russian company is about to introduce the culture of beet and manufacture of sugar. The climate promises success.

Siam.—Nachonyhaisi and Petno are the chief sugar districts, but the cane is also grown at Paklat, Bangpasoi, Chantibon, and Petchabure, to a considerable extent. The exports were 101,307 *piculs* (of 133⅓ lb.) in 1870. Our imports of unrefined were 20,107 cwt., 23,140*l.*, in 1877.

Spain.—The sugar-cane is cultivated in Spain on that portion of the Andalusian coast which lies between 36° and 37° N. lat. The area is very limited. Beet is about to be introduced.

Straits Settlements.—Our imports thence of unrefined sugar were 101,219 cwt., 83,762*l.*, in 1876; 195,527 cwt., 159,155*l.*, in 1880.

Surinam.—In 1879, the cane acreage was 4389 *hectares* (of 2½ acres); the crop yielded 11,023,130 *kilo.* (of 2·2 lb.) of sugar, and 2,501,928 *litres* (of 1¾ pint) of molasses; the exports were 11,633,892 *kilo.* of sugar, and 1,936,802 *litres* of molasses. Our imports thence of unrefined sugar were 81,232 cwt., 85,734*l.*, in 1876; 74,959 cwt., 86,069*l.*, in 1880; molasses: 642 cwt., 301*l.*, in 1876; 2307 cwt., 846*l.*, in 1880.

United Kingdom.—No sugar is at present produced in the United Kingdom, but beet-sugar was largely made at Lavenham, Suffolk, a few years since, and the industry will probably be revived at no distant future. For beet-culture in England, see pp. 1832–4, for sorghum-culture, p. 1914.

Starch-sugar and brewing compounds are largely manufactured in London; and extensive sugar-refineries exist in London, Bristol, Greenock, &c.

Our imports in 1880 were:—Refined and candy: from France, 1,586 416 cwt., 2,342,912*l.*; Holland, 876,471 cwt., 1,275,717*l.*; Germany, 244,645 cwt., 339,969*l.*; Belgium, 108,313 cwt., 155,340*l.*; United States, 103,396 cwt., 161,384*l.*; other countries, 116,833 cwt., 161,550*l.*; total, 3,036,074 cwt., 4,436,872*l.* Unrefined: Germany, 4,384,268 cwt., 4,728,916*l.*; British W. Indies, 2,578,971 cwt., 2,738,322*l.*; Java, 1,763,522 cwt., 2,226,225*l.*; Brazil, 1,484,924 cwt., 1,512,709*l.*; British Guiana, 1,327,084 cwt., 1,778,481*l.*; Philippines, 1,175,140 cwt., 983,590*l.*; Peru, 1,000,987 cwt., 1,128,062*l.*; Spanish W. Indies, 640,810 cwt., 770,673*l.*; Belgium, 493,349 cwt., 540,241*l.*; Madras, 487,048 cwt., 349,803*l.*; China, 359,821 cwt., 301,307*l.*; Holland, 205,601 cwt., 223,900*l.*; Straits Settlements, 195,527 cwt., 159,155*l.*; Egypt, 195,217 cwt., 229,381*l.*; Mauritius, 120,516 cwt., 137,021*l.*; France, 115,298 cwt., 136,089*l.*; Mexico, 94,879 cwt., 98,113*l.*; Chili, 79,658 cwt., 90,766*l.*; British S. Africa, 76,682 cwt., 76,720*l.*; Dutch Guiana, 74,959 cwt., 86,069*l.*; Danish W. Indies, 52,113 cwt., 63,859*l.*; Bengal and Burma, 25,851 cwt., 27,113*l.*; Honduras, 18,207 cwt., 18,273*l.*; New Granada, 17,919 cwt., 20,277*l.*; other countries, 33,262 cwt., 32,898*l.*; total, 17,001,613 cwt., 18,457,963*l.* Glucose, solid or liquid: Germany, 218,745 cwt., 213,166*l.*; United States, 100,467 cwt., 91,063*l.*; France, 70,151 cwt., 69,733*l.*; other countries, 16,397 cwt., 13,775*l.*; total, 405,760 cwt., 387,737*l.* Molasses: United States, 92,000 cwt., 39,685*l.*; British W. Indies, 42,476 cwt., 16,937*l.*; Egypt, 30,057 cwt., 9408*l.*; British Guiana, 20,888 cwt., 10,189*l.*; Germany, 3515 cwt., 1571*l.*; Mauritius, 3475 cwt., 1379*l.*; other countries, 19,130 cwt., 7082*l.*; total, 211,541 cwt., 86,251*l.*

Our exports in 1880 were:—Refined and Candy: Portugal, Azores, and Madeira, 28,031 cwt., 36,815*l.*; Malta and Gozo, 17,103 cwt., 23,338*l.*; Channel Islands, 15,411 cwt., 22,666*l.*; Australia, 13,039 cwt., 19;470*l.*; Argentine Republic, 8742 cwt., 12,972*l.*; Gibraltar, 7635 cwt., 10,663*l.*; Turkey, 5218 cwt., 7590*l.*; France, 3712 cwt., 4581*l.*; Roumania, 3426 cwt., 5108*l.*; British S. Africa, 3221 cwt., 5210*l.*; Norway, 2166 cwt., 3323*l.*; Persia, 2005 cwt., 2754*l.*; Morocco, 1456 cwt., 2130*l.*; China, 1157 cwt., 2703*l.*; Italy, 1149 cwt., 1540*l.*; other countries, 11,771 cwt., 16,924*l.*; total, 125,242 cwt., 177,787*l.* Unrefined Beet-sugar: Portugal, 12,132 cwt., 17,020*l.*; other countries, 2842 cwt., 3738*l.*; total, 14,974 cwt., 20,758*l.* Cane and other sorts: Denmark, 71,108 cwt., 82,703*l.*; Portugal and Azores, 60,977 cwt., 71,465*l.*; Sweden, 41,312 cwt., 53,371*l.*; United States, 38,960 cwt., 42,634*l.*; Belgium, 21,581 cwt., 24,705*l.*; Holland, 19,935 cwt., 22,558*l.*; Germany, 15,554 cwt., 17,947*l.*; Italy, 10,949 cwt., 14,916*l.*; France, 9200 cwt., 12,049*l.*; other countries, 9085 cwt., 11,337*l.*; total, 298,661 cwt., 353,685*l.* Glucose: Australia, 23,075 cwt., 21,800*l.*; other countries, 770 cwt., 807*l.*; total, 23,845 cwt, 22,607*l.* Molasses: British N. America, 13,457 cwt., 9165*l.*; Norway, 9938 cwt., 5015*l.*; other countries, 15,631 cwt., 9435*l.*; total, 39,026 cwt., 23,615*l.*

United States.—Cane-sugar is mainly produced, but also beet-, maple-, melon-, and sorghum-sugars, as well as very large quantities of starch-sugar. The home growth of cane-sugar in 1870 was 80 million lb., and of maple, 28 million. The New York imports of sugar in 1880 were:—Foreign direct, 555,553 tons; melado, 6239; Texas, 895; Louisiana, 5260; other coastwise, 5167; total, 573,114 tons. Of molasses:—Foreign direct, 10,393,585 gal.; Louisiana, 4,382,595; other coastwise, 73,580; total, 14,849,760 gal. Exports: Molasses, 2,626,947 dol. worth; sugar, 59,348,432 dol. worth. Our imports thence were:—Refined sugar: 439,914 cwt., 624,670*l.*, in 1879; 103,396 cwt., 161,384*l.*, in 1880; unrefined: 4623 cwt., 5056*l.*, in 1878; 14,796 cwt., 14,466*l.*, in 1880; molasses: 511,699 cwt., 186,219*l.*, in 1879; 92,000 cwt., 39,685*l.*, in 1880.

Venezuela.—The 1873 crop of cane-sugar was about 5,000,000 lb. The exports from Puerto Cabello in 1879 were 38,760 *kilo.* (of 2·2 lb.) to Holland.

W. Indies.—The areas under cane culture are as follows:—Jamaica, 47,565 acres; Barbados, 35,000 acres; Martinique, 19,314 *hectares* (of 2½ acres). Sugar production:—Barbados, 37,400 hhds.; Trinidad, 59,000; Grenada, 3800; St. Vincent, 9000; Tobago, 4000; Santa Lucia, 10,200; Martinique, 75,000; Dominica, 3700; Guadeloupe, 35,088,944 *kilo.*; Antigua, 7700 hhds.;

St. Kitts, 10,600; Porto Rico, 140,030,000 lb.; Jamaica, 29,074 hhds. Exports: Barbados, 1880, 54,217 hhds. sugar, 31,791 puns. molasses; Jamaica, 1874, 28,398 hhds. sugar; Dominica, 1871, 66,220 cwt. sugar, 94,015 gal. molasses; Montserrat, 1871, 1891 hhds. sugar, 466 puns. molasses; Trinidad, 1874, 99 million lb. sugar, 1½ million gal. molasses; St. Croix, 1873, 10 million lb. sugar, 350,000 gal. molasses; Porto Rico, 1873, 101,195 tons sugar, 6 million gal. molasses; Cuba, 1873, 714,960 tons sugar, 189,333 tons molasses. Our imports from the British W. Indies were:—Unrefined: 3,242,034 cwt., 3,056,564*l.*, in 1879; 2,578,971 cwt., 2,738,322*l.*, in 1880; molasses: 137,405 cwt., 56,385*l.*, in 1879; 42,476 cwt., 16,937*l.*, in 1880. French W. Indies:—Refined: 28,095 cwt., 35,411*l.*, in 1876; unrefined: 116,993 cwt., 169,739*l.*, in 1879. Spanish W. Indies:—Unrefined: 2,260,193 cwt., 2,299,764*l.*, in 1879; 640,810 cwt., 770,673*l.*, in 1880; molasses: 37,303 cwt., 15,604*l.*, in 1876; 156 cwt., 35*l.*, in 1880.

Zanzibar.—Exported 3000*l.* worth in 1864.

Consumption.—Following are approximate statistics of consumption in various countries:—

	Year.	Aggregate Consumption.	Lb. per Head.
		cwt.	
United Kingdom	1875	18,374,543	62·80
Holland	1874	800,000	25·03
Belgium	1874	1,000,000	23·19
Hamburg (imports)	1873	1,223,733	..
Germany	1874	6,120,000	16·60
Denmark	1873	533,831	33·30
Sweden	1873	630,741	16·90
Norway	1873	193,086	12·70
France	1874	5,000,000	15·50
Austria and Hungary	1874	3,400,000	15·10
Switzerland	1873	381,295	15·90
Portugal	1874	300,000	8·40
Spain	1873	81,817	0·54
Russia and Poland	1874	4,000,000	5·40
Turkey	1874	500,000	3·80
Greece	1871	86,800	6·60
Italy	1873	865,350	3·60
United States	1873	13,040,500	37·80
British America	1875	1,721,386	51·40
Brazil	1874	642,857	8·00
Peru	1874	570,000	5·61
River Plate States	1874	1,000,000	43·90
Other S. and Central American States	1874	500,000	..
W. India Islands (British and Foreign)	1874	1,000,000	..
N. and S. Africa	1874	1,000,000	..
Australia	1874	1,713,142	85·90
India, China, and the Eastern and Pacific Islands	..	25,000,000	..

Values.—The approximate London market values of sugars, per cwt., are:—Jamaica: fine, 20–25*s.*; good, 19*s.* 6*d.*–24*s.* 6*d.*; middling, 19–24*s.*; good brown, 18–23*s.* 6*d.*; ordinary brown, 17–22*s.* Demerara, Trinidad, &c.: fine, 20–24*s.*; good, 19*s.* 6*d.*–23*s.* 6*d.*; middling, 18*s.* 6*d.*–23*s.*; good brown, 17*s.* 6*d.*–22*s.* 6*d.*; ordinary brown, 16*s.* 6*d.*–21*s.* 6*d.*; crystallized, low, 23*s.* 6*d.*–30*s.*; do. medium, 25–31*s.*; do. good to choice, 27*s.* 6*d.*–33*s.* St. Lucia: good and fine, 19–24*s.*; middling, 18*s.* 6*d.*–23*s.*; brown, 16*s.* 6*d.*–22*s.* Barbados: low, 17*s.* 6*d.*–24*s.*; middling to fine, 19–26*s.* 6*d.*; grainy, 21*s.* 6*d.*–28*s.* 6*d.* Antigua, 17–24*s.* 6*d.* Concrete, 16*s.* 6*d.*–20*s.* Mauritius: crystallized, 23–29*s.*; grainy yellow, 20*s.* 6*d.*–27*s.*; yellow, 18*s.* 6*d.*–24*s.* 6*d.*; brown, good and fine, 17*s.* 6*d.*–22*s.*; brown, low, 16–20*s.* 6*d.* Benares, 23–25*s.* 6*d.* Bengal date: yellow to fine, 19–26*s.* 6*d.*; brown, low to fine, 13*s.* 6*d.*–23*s.*; Jaggery, 13–18*s.* Penang: yellow and white, 19–29*s.*; brown, 16*s.* 6*d.*–22*s.* 6*d.*; native, 13*s.* 6*d.*–17*s.* 6*d.* Natal, 14–29*s.* Egyptian: brown syrups, 15–20*s.*; yellow do., 17*s.* 6*d.*–21*s.* 6*d.*; white crystallized, 25–30*s.* Manilla: clayed, 16–21*s.* 6*d.*; unclayed, 13*s.* 3*d.*–18*s.* 6*d.* Java: grey and white, 22–30*s.*; brown and yellow, 17*s.* 6*d.*–26*s.* 6*d.*; brown syrups, 13–15*s.*; No. 14 to 15, afloat, 24–29*s.* China and Siam: yellow, 18*s.* 6*d.*–24*s.* 6*d.*; brown, 14–22*s.* Porto Rico: good and fine, 20–25*s.*; middling, 19–21*s.*; brown, 17*s.* 6*d.*–18*s.* 6*d.* Brazil: white and grey, 20–26*s.*; yellow, 18*s.* 6*d.*–24*s.* 6*d.*; brown, 15–22*s.* Beet: French crystals, 25–27*s.*; do. new 88 per cent., 21–25*s.*; Austrian, 88 per cent., 20–25*s.* Refined: Titlers, 26–34*s.*; loaves, 29–32*s.*; cubes, 28–35*s.*; pieces, fine, 21–31*s.*; do. good and ordinary, 18–26*s.*; bastards, 16–23*s.*; Hamburg: crushed, 28–30*s.* 6*d.*; treacle, 11–17*s.*; Dutch: loaves, 25–28*s.*; crushed, No. 1, 25–30*s.*; Belgian: loaves, 26*s.*; crushed, 25*s.* 6*d.*; Paris loaves, 26–31*s.* Candy, 28–42*s.* Molasses: British W. Indian, 9–12*s.*; Australian, 8–8*s.* 6*d.*; British treacle, 13–16*s.*

Bibliography.—B. Higgins, 'Muscovado Sugar and Rum' (St. Jago de la Vega: 1800); T. Roughley, 'Jamaica Planter's Guide' (Lond.: 1823); J. Bell, 'Culture of the Sugar-cane, and Distillation of Rum' (Calcutta: 1831); B. Silliman, 'Cultivation of the Sugar-cane' (Washington: 1833); E. Peligot, 'Analyse et Composition de la Betterave à Sucre' (Paris: 1839); E. Peligot, 'Composition Chimique de la Canne à Sucre' (Paris: 1840); G. R. Porter, 'The Sugar-cane' (Lond.: 2nd ed., 1843); E. Peligot, 'Fabrication du Sucre' (Paris: 1843); Marquis de St. Croix, 'Fabrication du Sucre aux colonies françaises' (Paris: 1843); W. J. Evans, 'Sugar-planter's Manual' (Lond.: 1847; Philad.: 1848); John A. Leon, 'Sugar Cultivation in Louisiana' (Lond.: 1848); L. Wray, 'The Practical Sugar Planter' (Lond.. 1848); R. S. McCulloh and A. D. Bache, 'Scientific Investigations on Sugar and Hydrometers' (U. S. Senate Doc. No. 209, and [revised ed.] No. 50, Washington: 1848); S. H. Robinson, 'The Bengal Sugar-planter' (Calcutta: 1849); J. Scoffern, 'Manufacture of Sugar in the Colonies and at Home' (Lond.: 1849); J. A. Leon, 'Manufacturing and Refining Sugar' (Lond.. 1850); T. Kerr, 'Cultivation of the Sugar-cane and Manufacture of Sugar' (Lond.: 1851); W. K. Sullivan, 'Prospects of Beet Sugar in Ireland' (Dublin: 1852); H. Bessemer, 'New System of Manufacturing Sugar' (Lond.: 1852); P. Madinier and G. de Lacoste, 'Guide du Cultivateur du Sorgho à Sucre' (Paris: 1856); H. S. Olcott, 'Sorgho and Imphae, the Chinese and African Sugar-canes' (New York: 1857); A. W. Anderson, 'Sugar-cane and Manufacture of Sugar in the W. Indies' (Trinidad: 1860); Malavois, 'Culture de la Canne et fabrication du sucre à l'île de la Réunion' (Paris: 1861); D. M. Cook, 'Culture and Manufacture of Sugar from Sorghum' (Rep. Com. Pat., Washington: 1862); N. P. Burgh, 'Sugar Machinery' (Lond.: 1863); L. S. Bouton, 'Espèces de cannes à sucre cultivées à Maurice' (Port Louis: 1863); J. A. Hedges, 'Sorgo, or the Northern Sugar Plant' (Cincinnati: 1863); R. Niccol, 'Sugar, and Sugar Refining' (Greenock: 1864); E. Icery, 'Recherches sur le jus de la Canne à Sucre' (Maurice: 1865); A. Bobierre, 'Culture de la Canne à Sucre' (Paris: 1865); A. Reynoso, 'Cultivo de la Caña de azucar [in Cuba]' (Madrid: 2nd ed. 1865); C. Antelme, 'Culture de la Canne à Sucre à l'île Maurice' (Bordeaux: 1866); W. Reed, 'History of Sugar and Sugar-yielding Plants, and Epitome of Processes of Manufacture' (Lond.: 1866); P. F. Nursey, 'Sugar-making Machinery' (Trans. Soc. Engineers, Lond.: 1866); N. P. Burgh, 'Manufacture of Sugar, and Machinery employed' (Jour. Soc. Arts, Vol. xiv., No. 698, Lond.: 1866); E. B. Grant, 'Beet Sugar' (Boston: 1867); F. L. Stewart, 'Sorghum and its Products' (Philad.: 1867); 'Sugar made from Maize and Sorghum' (Washington: 1878); N. Basset, 'Culture de la Betterave' (Paris: 3rd ed. 1868); 'Guide du Fabricant de sucre' (Paris: 2nd ed. 1872–5); 'La Sucrerie' (Paris); 'La Situation de l'industrie sucrière française' (Paris: 1873); J. Blondel, 'Fabrication du sucre de Betteraves' (Douai: 2nd ed. 1870); W. Crookes, 'Beetroot Sugar in England and Ireland' (Lond.: 1870); A. Baruchson, 'Beetroot Sugar' (Lond. 2nd ed.. 1870); C. Stammer, 'Fabrication du Sucre' (Paris: 1870); L. Walkhoff, 'Fabrication et Raffinage du Sucre de Betteraves' (Paris and Kiew: 1870–1); A. Voelcker, 'Cultivation and Uses of Sugar-beet in England' (Jour. Soc. Arts, Vol. xix., No. 955, Lond.: 1871); F. Kohn, 'Methods of Extracting Sugar from Beetroot and Cane' (Jour. Soc. Arts, Vol. xix., No. 956, Lond.: 1871); W. Anderson, 'The Aba-el-Wakf Sugar Factory, Upper Egypt' (Min. Proc. Inst. Civ. Engs., Vol. xxxv., Lond.: 1872); P. Soames, 'Manufacture of Sugar from the Sugar-cane' (Lond.: 1872); C. H. Gill, 'Manufacture and Refining of Sugar' (Cantor Lecture, Soc. Arts, Lond.: 1872); A. P. Dubrunfaut, 'Le Sucre' (Paris: 1873); T. L. Phipson, 'Agricultural Chemistry of the Sugar-cane' (Lond.: 1873); J. A. Benoit, 'Culture speculative de la Betterave' (Troyes: 1874); E. Frémy and P. P. Dehérain, 'Les Betteraves à Sucre' (Paris: 1875); H. T. Chamberlain, 'The Sugar Trade of Bristol' (Jour. Soc. Arts, Vol. xxiii., No. 1190, Lond.: 1875); Massonneau, 'Betterave à sucre, sa culture et ses produits' (Poissy: 1875); J. Duncan and J. A. R. and B. E. R. Newlands, 'The Alum Process for purifying Sugar' (Lond.: 1875); P. Champion and H. Pellett, 'La Betterave à Sucre' (Paris: 1876); B. Corenwinder, 'Influence de l'effeuillaison des betteraves sur le rendement et la production du sucre' (Paris: 1876); C. Lenglen, 'Culture de la betterave' (Arras: 1876); A. Petermann, 'Culture de la betterave à sucre' (Brussels: 1876); E. J. Maumené, 'Fabrication du Sucre' (Paris: 1876–8); John Shier, 'Testing Cane-juice, and the Process of Clarification' (Lond.. 2nd ed., 1877); J. Clibborn, 'Sugar-cane Crushing Mill' (Profes. Pap. Indian Eng., Vol. vi., No. 26, Roorkee: 1877); C. Scheibler, 'Rübenzuckerfabrikation' (in A. W. Hofmann's 'Chemische Industrie,' III. Heft, Brunswick: 1877); P. L. Simmonds, 'Tropical Agriculture' (Lond.: 1877); A. Ladureau, 'Culture de la betterave à sucre' (Lille: 1877, 1880); G. Maw, 'The Sugar Maple' (Pharm. Jour., Vol. ix. [xxxviii.], No. 428, Lond.: 1878); B. Corenwinder and C. Contamine, 'L'influence des feuilles sur la production du sucre dans les betteraves' (Lille: 1879); V. Drummond, 'Report on Production of Sugar from Sorghum' (1879); Horsin-Déon, 'L'Industrie Sucrière' (in 'Etudes sur l'Exposition de 1878,' Paris: 1879–80); L. S. Ware, 'The Sugar-beet' (Philad.: 1880); H. Ling Roth, 'The Sugar Industry in Queensland' (Brisbane, Sydney, Melbourne, and Lond.: 1880); W. G. Le Duc, 'Sorghum Sugar' (Washington: 1880); W. Ingram, 'Sorghum Cultivation at Belvoir' (Lond.: 1880); J. Frankel and R. Hutter, 'Starch,

Glucose, Starch-sugar, and Dextrine' (Philad. and Lond.: 1881); J. H. Tucker, 'Manual of Sugar Analysis' (New York: 1881); R. Frühling and J. Schultz, 'Untersuchung der für die Zucker-industrie Rohmaterialien' (Brunswick: 1881); L. Lepaire, 'Culture de la betterave' (Chalon sur Saône: 1881); G. Kleemann, 'Praktische Zuckerrübenbau (Leipzig: 1881); F. Rehwald, 'Stärke-Fabrikation, u. Fabrikation des Traubenzuckers' (Vienna, Leipzig, and Pest); P. H. F. Bourgoin d'Orli, 'Culture de la Canne à Sucre' (Paris); R. von Regner, 'Fabrikation des Rübenzuckers' (Vienna, Leipzig, and Pest); 'Journal des Fabricants de Sucre' (Paris: 1866–); 'The Sugar Cane' (Manchester: 1869–); 'Zeitschrift für Zucker-industrie' (Prag: 1872–); R. H. Harland, 'Manufacture of Sugar from Sugar-cane' ('The Analyst,' Lond: 1880).

TANNIN (FR., *Matières tannantes*; GER., *Gerbstoffe*).

The word "tannin" does not, as formerly supposed, denote a single definite compound, but is a generic name applied to a large class of organic bodies, mostly uncrystallizable, which often differ widely both in chemical constitution and reaction, but have the common property of precipitating gelatine from its solution, and forming insoluble compounds with gelatine-yielding tissues. By virtue of this power, they convert animal hide into the insoluble and imputrescible material called "leather" (see pp. 1213–40). They all form blackish-blue or blackish-green compounds with ferric salts, and are precipitated by acetate of lead and of copper; but these properties are common to many other organic substances. They give insoluble precipitates with many organic bases, and with a large number of metallic salts. In some cases, the tannin combines with the base only, liberating the acid; but frequently the salt as a whole enters into combination. This is the case with the precipitates formed with acetates of lead and copper. With alkalies, the tannins and many of their derivatives give solutions which oxidize and darken rapidly, usually becoming successively orange, brown, and black. A. H. Allen has shown that these bodies also give instantaneously a deep-red coloration with a solution of potassium ferricyanide and ammonia. The reaction is one of considerable delicacy.

The tannins are very widely distributed through the vegetable kingdom. They are probably to be regarded in most cases rather as waste products eliminated by the plant, than as bodies stored up for future nutrition, like starch and sugar, and are enclosed in the tissue-cells.

General Chemistry.—A large number of plants, from every part of the world, contain principles varying in properties and constitution, but having the common characteristics of an astringent taste, of precipitating gelatine from solution, and of giving a blackish coloration with persalts of iron. The whole class are denominated "tannins;" but it is obvious that the different tannins are often widely distinct, and that the general statements frequently made are usually true only of certain individual members of the group. On the same grounds, it may also be concluded that any general method of analysis can only give arbitrary percentages, which afford no safe means of comparing tannins of different species, although it may be of considerable use in deciding the relative values of different samples of the same material.

From the tanner's point of view, tannins may be divided into two principal classes, viz. those which produce a light fawn-coloured deposit on leather (technically known as "bloom"), and those which do not. To the first of these, belong the tannins of gall-nuts, valonia, oak-bark, myrabolans, sumach, and divi-divi, while the second includes cutch, gambier, hemlock, larch, rhatany, and mangrove, and all the varieties of mimosa. Bearing in mind that the same plant frequently contains more than one species of tannin (of which the different characters of the tannins of gall-nuts, valonia, and oak-bark, all produced by oaks, is a striking example), it will appear that this classification is generally coincident with an important difference of chemical constitution; most tannins which give "bloom" are derivatives of gallic acid (see Acid—Gallic, pp. 50–1), while those which deposit insoluble red and brown colouring matters are derived from protocatechuic acid,—oak-bark and valonia excepted. To the chemical student, it may be interesting to note that both these bodies are benzene derivatives, belonging to the "aromatic" group of carbon compounds, of which benzene is the simplest type. Their relation is shown by the following formula:—

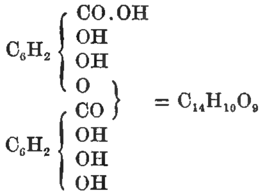
Benzene.	Gallic acid.	Protocatechuic acid.
C_6H_6	$C_6\begin{cases}H_2\\(OH)_3\\CO.OH\end{cases} = C_7H_6O_5$	$C_6\begin{cases}H_3\\(OH)_2\\CO.OH\end{cases} = C_7H_6O_4$

Stenhouse attempted some years since to separate tannins into two classes, according to the bluish- or greenish-black which they gave with persalts of iron. It has been shown that this is dependent in some cases on associated impurities, and it is influenced by the amount of acidity of the iron solution used, gallic and gallotannic acids giving a deep green coloration with strongly acid ferric chloride, while with ferric acetate they give a blue- or purple-black. As a general rule, however, it may be stated that the tannins which give a blue- or purple-black with ferric acetate are gallic-acid derivatives, and likely to give bloom to leather; while those which give a green-black are derived from protocatechuic acid, and will probably yield no bloom. Gallic and pyrogallic acids give with ferric acetate a purple-black; while protocatechuic and pyrocatechuic acids give a dark-green.

When natural tannins are boiled with dilute sulphuric acid, they are decomposed, generally yielding glucose, often also insoluble red bodies, called phlobaphenes. These bodies, when fused with caustic potash, give protocatechuic acid, and either acetic acid or a peculiar sugar called phloroglucine. Hlasiewetz gives the following table of the derivatives of tannin so treated:—

Source of Tannin.	Name of Tannin.	Products on boiling with Sulphuric Acid.	Product of the last column fused with Caustic Potash.
Gall-nuts	Gallotannic acid	Glucose and gallic acid	Pyrogallic and carbonic acids.
Pomegranate-bark, in company with gallotannic acid in sumach, myrabolans, &c. ..	Pomegranate tannin	,, ellagic ,,	Gallic acid (?)
Coffee	Caffetannic acid	,, caffeic ,,	Protocatechuic and acetic acids.
Cinchona-bark	Quinatannic ,,	,, quina red	,, ,,
,, ,, ...	Quinovatannic ,,	,, quinova ,,	,, ,,
Male fern	Filicitannic ,,	,, filix ,,	,, ,,
Rhatany-bark	Rhataniatannic ,,	,, rhatania ,,	Protocatechuic acid and phloroglucin.
Chestnut	Chestnut tannin	,, chestnut ,,	,, ,,
Cutch and gambier ..	.. ..	Catechin	,, ,,
Fustic (*Morus tinctoria*)	.. ..	Maclurin or morin-tannic acid	,, ,,

From Hlasiewetz's table, it would appear that a very large proportion of tannins yield glucose on digestion with a dilute mineral acid. They appear, however, to differ materially from the class of bodies known as glucosides, which are generally crystalline, and yield their glucose very easily under the influence of acids, while tannins (except perhaps morintannic acid) are amorphous, and require somewhat prolonged digestion. Hlasiewetz suggests that they may be "gummides," or compounds containing gum or dextrine, which is converted by digestion with acid into glucose (see pp. 1914–21). But it is by no means certain that glucose should be regarded as an essential constituent of tannins, since, by repeated precipitations with lead acetate, and decomposition of the tannate with sulphuretted hydrogen, gallotannic acid may be prepared almost free from any glucose, yielding constituent, and retaining all its characteristic properties. Schiff, by acting on gallic acid with phosphorus oxychloride, has produced gallotannic acid synthetically, and this artificial tannin yields no glucose, but only gallic acid, by digestion with acids. This synthesized tannin appears to be *di*gallic acid, formed from two molecules of gallic acid by the simple abstraction of one molecule of water. Thus, its constitutional formula is



$$\left.\begin{array}{l} C_6H_2\left\{\begin{array}{l} CO.OH \\ OH \\ OH \\ O \end{array}\right. \\ C_6H_2\left\{\begin{array}{l} CO \\ OH \\ OH \\ OH \end{array}\right. \end{array}\right. = C_{14}H_{10}O_9$$

Natural gallotannic acid is probably a molecular compound of this digallic acid with glucose or dextrine.

In digesting ordinary gallotannic acid, from gall-nuts, sumach, myrabolans, and other sources, with sulphuric acid, or in its decomposition by natural fermentation, besides glucose and gallic acid, a varying quantity of a grey or fawn-coloured deposit of ellagic acid is always produced. This is closely allied to tannic (digallic) acid, differing from it only by the abstraction of 2 atoms of hydrogen, and may be produced from it by heating it with dry arsenic acid (which oxidizes the hydrogen). It is, however, probable that it is produced in the cases named from a peculiar tannic acid, called by Löwe ellagitannic acid, which exists in divi-divi, myrabolans, pomegranate-rind, and other materials, in mixture with ordinary gallotannic acid. This body is what Hlasiewetz calls "pomegranate tannin." Oak-bark and valonia yield abundant light-coloured deposits, which are probably ellagic acid.

On heating dry gallotannic or gallic acids to 180°–210° (356°–410° F.), they are decomposed, and partially sublime in white prismatic plates of pyrogallol, or pyrogallic acid, while a black residue of metagallic acid remains. By heating a solution of gallic acid in glycerine to 200° (392° F.), it is completely converted into pyrogallol, without production of metagallic acid.

Pyrogallol ($C_6H_6O_3$) has a feebly acid and very bitter flavour. It fuses at 131° (268° F.), is soluble in less than 3 parts of cold water, and still more soluble in hot. It is also soluble in alcohol and ether, but not in absolute chloroform. In presence of alkalies, it absorbs oxygen with great avidity, turning brown or black. It reduces Fehling's solution, and those of gold and silver, and gives purplish-blacks with ferric and ferrous salts. Probably its most characteristic reaction is the fine but very fleeting purple coloration which it gives with lime-water. Since all vegetable extracts containing gallic or gallotannic acids yield pyrogallol, its production has been used as a test for the presence of these bodies by Stenhouse, thus distinguishing again between the two classes of tannins derived from gallic and protocatechuic acids respectively. It is a singular fact that although oak-bark and valonia tannins give blue-blacks with iron salts, and yield abundant white deposits supposed to be ellagic acid, they give no pyrogallic acid on heating; but on the contrary, are stated by Johansen to yield protocatechuic acid on fusion with potash. They thus present important differences from gallotannic acid on the one hand and from most red-yielding tannins on the other, and urgently demand further investigation. Experiments made by the writer suggest the probability that oak-bark tannin contains phloroglucin as well as protocatechuic acid.

Associated with different species of catechutannic acids in cutch and gambier, considerable portions of a white crystalline body (or possibly class of bodies) are found. This is catechin. It is contained in large quantity in cube gambier, forming a great part of the pale-coloured crystalline interior. It is readily soluble in boiling water, but very slightly so in cold; hence, on allowing a boiling solution of gambier to cool, it is deposited in large quantities as a whitish sediment. Its solution does not precipitate gelatine. Its relation to the tannins of cutch and gambier is not well made out, but they seem to be anhydrides. Its lower anhydrides are soluble in water, and precipitate gelatine; while with every successive molecule of water which they give up, they become more insoluble, and the higher anhydrides are reds similar to phlobaphene, insoluble in water and ether, but soluble in alcohol. Thus to an extent the relations between catechin and the catechu tannins are similar to those between gallic acid and gallotannic acid, but catechin is a body of much more complicated structure than gallic acid. Its formula is probably $C_{19}H_{18}O_8$, and both it and its anhydrides, when fused with potash, yield protocatechuic acid and phloroglucin.

It may be well to remark here that the question of hydration plays an important and imperfectly understood part in the chemistry of tannin. When hemlock tannin is reduced to a thick extract by evaporation in the vacuum-pan, it appears to part with some of its combined water, and a portion only of the tannin is soluble in cold water, the remainder being precipitated as an insoluble anhydride or phlobaphene, which cannot be dissolved even by subsequent boiling. If, on the other hand, water of as high a temperature is employed as has been used in the evaporation of the extract, the whole is brought again into solution, unless the extract has been thickened at too high a temperature. This is true of most tanning extracts besides hemlock.

It will thus be obvious that our knowledge of the chemistry of the various tannins is very imperfect, and it is useless to try to fill up the gaps by mere speculation.

As regards analytical examination of mixtures of tannins, a quantitative separation of the different species is as yet quite impossible; but qualitatively, tannins may at least be detected when not in too complicated mixture. The following table gives distinctive reactions of some of the principal tannins and their derivatives.

Reagent.	Gallotannic Acid.	Gallic Acid.	Pyrogallic Acid.	Oak Bark Infusion.	Solution Pegu Cutch.
Baric chloride and ammonia.	Blue ppt.	Blue ppt.	Brown coloration.	Brown ppt.	Slight ppt.
Bromine-water.	Nil.	Nil.	Nil.	Pale „	Dense buff ppt.
Lime-water.	Ppt. turning blue.	Ppt. turning blue.	Deep violet colour.	Brown „	Slight ppt., soluble in excess.
Copper sulphate.	Nil.	Nil.	Nil.	Slight „	Dense ppt.
Ferric acetate.	Blue-blk. ppt.	Purple-blk. ppt.	Purple-blk. colour.	Blue-blk. ppt.	Green-blk. ppt.
Lead nitrate.	White ppt.	Nil.	Nil.	Brown ppt.	Nil.
Gelatine.	Ppt.	Nil.	Nil.	Ppt.	Cloudy ppt.

The infusions used should be very dilute, not exceeding 5° of the barkometer (sp. gr. 1·004).

A. H. Allen, in his 'Commercial Organic Analysis,' gives the following table for the distinction of gallic, pyrogallic, and gallotannic acids:—

	Reagent.	Gallic Acid.	Pyrogallic Acid.	Gallotannic Acid.
1	With solution of gelatine.	No change except in presence of gum.	No change.	White or brownish ppt.
2	Heated with Fehling's solution.	No change.	Reduction and precipitation of Cu_2O.	Reduction and precipitation of Cu_2O.
3	With ferrous sulphate free from ferric salt.	White ppt. concentrated; no change dilute.	Blue solution.	White concentrated; no change dilute.
4	With ferric chloride.	Deep blue colour destroyed by boiling.	Red colour, turning brown when heated.	Blue-black ppt.; colour destroyed by boiling.
5	With excess of lime-water.	White precipitate becoming purple or deep brown very rapidly.	Immediate purple colour, changing to brown in the air.	White precipitate slowly darkening.

Quantitative Determination.—Many processes have been proposed for the quantitative estimation of tannins, but it cannot be said that any method yet known is wholly satisfactory. The oldest, that of Sir H. Davy, recently improved by Stoddart and others, consists in precipitating with gelatine, and drying and weighing the precipitate. This was almost impossible to filter off as directed by Davy; but by the use of a little alum, and by pouring hot water on the precipitate, it becomes curdled into a mass which may be washed by decantation. As the precipitate contains varying quantities of tannin, according to the strength of solution employed; as it is soluble in excess of gelatine solution, and as it is almost if not quite impossible to wash it free from gelatine and alum, the method can hardly lay claim to much accuracy. A somewhat better one consists in the employment of a standard solution of gelatine with a little alum, determining the end of the reaction by filtering off a portion and ascertaining if another drop of the reagent produces a further precipitate. This method is very tedious, the end reaction is difficult to hit, the standard solution is very unstable, it is inapplicable to gambier and cutch because the mixture will not filter clear, and its results are irregular, probably from the power of tannin to combine with various proportions of gelatine. A third plan, which has a most seductive appearance of simplicity, is that of Hammer; he takes the sp. gr., then absorbs the tannin with slightly moistened hide-raspings, again takes the sp. gr., and from the difference calculates the percentage of tannin, a difference of 5 per cent. of tannin corresponding to one of 1·020 sp. gr. (20° barkometer). Unfortunately the hide is more or less soluble in the liquor, and absorbs acids other than tannic with considerable energy; the moistening of the raspings introduces an error, and the smallness of the quantity to be measured makes a slight error completely vitiate the results. With extreme care, due corrections for temperature, for the water introduced with the raspings, and for their solubility, and by substituting evaporation of the infusions to dryness for mere calculation from their sp. gr., the method is useful as giving almost the only information obtainable as to the actual weight of tannin in any material capable of being absorbed by hide. It is, however, only suitable for use as a check on easier and more rapid methods, such as Löwenthal's, which give accurate relative results, but no information as to absolute weight of unknown tannins. A modification of Hammer's method has been introduced by Müntz and Ramspacher, in which the liquor whence the tannin is to be removed is forced through a piece of raw hide by pressure. This method, except that it is more rapid, has all the evils of Hammer's original in an intensified form, and gives such variable results as to be quite useless in practice.

Several other methods have been proposed: such as Gerland's, with a volumetric solution of tartar emetic, used in presence of ammonic chloride; Fleck's, by precipitation with acetate of copper, and subsequent washing with ammonic carbonate and gravimetric estimation, either of the tannate dried at 100° (212° F.), or of the oxide of copper left on ignition; and Carpene's, by precipitation with ammoniacal zinc acetate, and subsequent estimation with permanganate and indigo. These, though giving fairly accurate results on some tannins, are only of limited application. They may be passed over, as well as Jean's method with a volumetric solution of iodine in presence of sodic carbonate, and Allen's method with acetate of lead, which, though accurate, are somewhat tedious and difficult, and present no advantage over Löwenthal's improved process. This last is easy of execution, constant in results, and universally applicable. Before proceeding to describe it in detail, it may be well to give some hints as to the best modes of sampling and preparing tanning materials for analysis, since this is often more difficult and tedious than the actual analysis.

Sampling.—Samples should always be drawn from at least 10 sacks or separate parts of the bulk, and, in the case of valonia, special care should be taken to have a fair average quantity of "beard." If several sacks are spread in layers on a level floor, and then portions going quite to the ground are taken from several parts of the floor, this will be accomplished. Where samples must be dealt with which have not been specially drawn, it might be safest to weigh out from each the same proportion of beard and whole cups, bearing in mind that the beard is always the richest part of the valonia. In sampling myrabolans, it should be remembered that the poor and light nuts will rise to the top, and hence the hand should be plunged well into the sack. Grinding when practicable is probably best done in a small disintegrator, fitted with gratings. The material, of which some pounds must be used, is screened over a sieve of say 15 wires per in., and all coarser parts are returned to the mill till they will pass. The mill must grind into a close box, that no dust may be lost. The advantage of this plan is that samples can be ground without previous drying, and thus in many cases time may be saved and separate determination of moisture avoided. When this is not practicable, the sample of some lb. at least is ground in an ordinary bark-mill, well mixed, spread out flat on a floor or table, and several portions are taken as already described, say 50–100 *grm.* in all, and dried in a water- or air-oven at 100° (212° F.). The moisture is best determined, to save time, in a small separate portion of 10 *grm.*, which must be dried till it ceases to lose weight, and the loss taken as moisture. It must be weighed in a covered capsule, as it is very hygroscopic. When the larger portion of the sample has been dried some hours, it is passed twice through a good coffee-mill, and then returned to the oven till thoroughly dried, for which, 12–24 hours is generally sufficient. Another method sometimes convenient is to take each acorn, or each piece of bark of the sample to be tested, and snip a piece from it with a pair of tinners' shears, taking care that in the case of valonia the section runs right to the centre of the cup; and in bark, that fair shares of the outer and inner layers are taken. The reason for drying before grinding is, that unless hard dried, tanning materials cannot be passed through a small mill. Bark and valonia usually contain 12–16 per cent. of moisture.

Löwenthal's Process: Exhaustion.—10 *grm.* of valonia, 20–30 *grm.* of bark, or corresponding quantities of other materials, are boiled for 10 minutes with 250 *cc.* of distilled water, great care being taken at first to avoid frothing and boiling over. The clear liquid is then poured into a gauged flask, the residue is boiled up for 10 minutes, a second and a third time, with 250 *cc.* of water, and is finally rinsed into the flask, allowed to cool to 15° (59° F.), and made up to 1 *litre.* In the case of sumach, a little more boiling even than this is desirable. Another method is to boil for ½ hour with 250 *cc.* of water, then pour the whole on a filter, wash with boiling water so long as a drop of the filtrate blackens paper moistened with a dilute solution of ferric acetate, and finally make up to 1 *litre.* Many materials, however, clog the filter to such an extent that washing is almost impossible. Kathreiner uses 15 *litres* of water, and corresponding quantities of material, in a large steam-jacketed copper pan, for each exhaustion, making the weight up finally to 15 *kilos.*, and obtains very uniform and excellent results. With all materials which deposit ellagic acid or other insoluble derivatives, on cooling and standing, considerably higher results will be obtained if the titration be made as soon as the liquor is cold, than if it be allowed to stand 24 hours; in this respect, a uniform practice should be adhered to. Addition of ½ *cc.* of glacial acetic acid renders the infusions less liable to change.

Reagents.—Solutions are required of (1) Pure permaganate of potash, 1 *grm.* per *litre.* (2) Pure sulphindigotate of potash, 6 *grm.*, and concentrated sulphuric acid, 50 *grm.* per *litre.* (3) Pure oxalic acid, 10 *grm.* per *litre.* The sulphindigotate of potash (indigo carmine), must be filtered, and when oxidized by permanganate, should give a pure clear yellow, free from any trace of brown or orange. Any contamination with indigo purple, which gives brown oxidation-products, is quite fatal to the accuracy of the analysis. The permanganate solution is standardized by measuring 10 *cc.* of the (decinormal) oxalic acid solution, adding a little pure sulphuric acid and distilled water, warming to 58° (136° F.), and running in the permanganate till a faint permanent pink is produced, for which about 50–51 *cc.* should be required. The indigo-carmine solution should be of such strength that 14–16 *cc.* of permanganate are required to bleach the quantity employed, which may be 20–25 *cc.*, as convenient. (4) Gelatine solution: 25 *grm.* of gelatine or finest glue are dissolved in 1 *litre* of water, and saturated with table-salt. (5) Salt and acid solution: to a saturated solution of common salt, are added 50 *cc.* of concentrated hydrochloric acid per *litre.*

Actual Analysis.—25 *cc.* of indigo solution are diluted to about ¾ *litre* with distilled or good drinking-water in a white porcelain basin, and the permanganate solution is added drop by drop from a burette with constant stirring till the last trace of green disappears. Call the quantity of permanganate used A. 25 *cc.* of indigo solution and 10 *cc.* of the tannin infusion are treated as above. Let the quantity of permanganate be B. (If it exceeds 25 *cc.*, less tannin infusion must be taken, and the results calculated accordingly.) 100 *cc.* of the tannin infusion are well mixed with 50 *cc.* of gelatine solution, and then with 100 *cc.* of salt solution, shaken for some minutes, allowed to stand several hours, and filtered. The filtrate should be perfectly bright and clear. 50 *cc.* of this filtrate (=20 of original infusion) are titrated with permanganate and indigo as before described, the permanganate being run in *very* slowly, 5–6 minutes being taken for the process. Let this be called C; it is the amount required to oxidize the "not-tannin."

Then $B - A - \frac{1}{2}(C - A)$ is the quantity of permanganate required to oxidize the tannin. 4·156 *grm.* of pure gallotannic acid (Neubauer) and 6·236 *grm.* of oak-bark tannin (Oser) are said to be equivalent to 6·3 *grm.* of oxalic acid, and these numbers may be used to calculate percentages; but as the equivalents of most tannins are unknown, it would probably be better simply to calculate out the equivalent percentage of oxalic acid, which does not differ sensibly from that of oak-bark tannin. Then calling T the permanganate consumed by the tannin of 10 *cc.* infusion, O that required by 10 *cc.* of the oxalic solution, and x the percentage, and supposing 10 *grm.* of substance to be employed, $O : T :: 100 : x$; or the quantity of permanganate required to oxidize the tannin, divided by that required to oxidize the oxalic acid, and multiplied by 100, gives the percentage. Gallic acid needs more permanganate than the same weight of tannic acid, or even than the quantity of tannic acid from which it is derived.

A slight error is introduced by the presence of a trace of oxidizable matter in the glue, and when very great accuracy is required, it is well to make a blank estimation of "not-tannin" without tannin infusion, and deduct $\frac{1}{2}$ of the permanganate consumed as a correction from the not-tannin; but this may usually be disregarded. Each titration should be made twice, and successive tests should not differ by more than 0·1 *cc.* of permanganate.

It is obvious that it is impossible by analysis to compare the relative values of different tannins, such as those of myrabolans and gambier, or hemlock and valonia. All analysis can reasonably be expected to do is to give the relative values of different samples of the same substance, or at the most, of materials of the same class. All other comparisons are misleading; and would be so, even if the exact percentage of each tannin could be calculated; since the commercial and practical value of different materials does not depend on the quantity of tannin only, but on the character of the leather it produces, hard or soft, dark- or light-coloured, and heavy- or light-weighing.

H. R. P.

Algarobilla.—The seed-pods of *Prosopis pallida* and *P. Algarrobo* are known as *algarobilla*, the two kinds being distinguished as *negro* and *blanco*. The trees are abundant in mountainous parts of S. America, notably Chili and the Argentine Republic. The pods contain up to 50 per cent. of a bright-yellow tannin, somewhat resembling that of myrabolans. The friable tannin is readily soluble in cold water, and is so loosely held in the fibrous network of the pod, that great loss is sustained by careless handling. The commerce in algarobilla does not figure in the official trade returns; but J. Gordon & Co., Liverpool, obligingly state that they imported 50 tons, at an average value of 18*l.* 10*s.* a ton, in 1880. Widow Duranty & Son, also of Liverpool, are good enough to add that they received 160 tons in 1881, the first that had reached them for a long time. Havre imported 50 tons in 1881.

The name *algarrobo* is also applied to *Balsamocarpon brevifolium* in Chili, and to *Hymenæa Courbaril* (see p. 1666) in Panama.

Chestnut-extract.—The wood of *Castanea vesca* (see Nuts—Chestnut, pp. 1352–3; Timber) contains 14–20 per cent. of a dull-brown tannin. It is quite different from the bark and bark-extract of the American chestnut-oak (*Quercus sessiliflora*). Its extract is used largely to modify the colour produced by hemlock-extract, and for tanning and dyeing. The pulverized wood is also extensively employed in France. The imports are included in barks and extracts, p. 1988.

Cork-bark. See Oak-barks.

Cutch, Catechu, or Terra Japonica (Fr., *Cachou*; Ger., *Catechu*).—The term *kát*, *kut*, or "cutch," is applied to the dried extract, containing 45–55 per cent. of dark-coloured mimotannic acid, prepared chiefly from two trees:—(1) *Acacia Catechu* [*Mimosa Catechu*, *M. sundra*], a tree of 30–40 ft., common in most parts of India and Burma, growing also in the hotter and drier districts of Ceylon, and abundant in tropical E. Africa—the Soudan, Sennar, Abyssinia, the Noer country and Mozambique, though the utilization of its tannin is restricted to India; (2) *A.* [*M.*] *Suma*, a large tree inhabiting S. India (Mysore), Bengal, and Gujerat.

The process for preparing cutch varies slightly in different districts. The trees are reckoned to be of proper age when their trunks are about 1 ft. diam. They are then cut down, and the whole of the woody part, with the exception of the smaller branches and the bark, is reduced to chips: some accounts state that only the darker heart-wood is thus used. The chips are placed with water in earthen jars, arranged in a series over a mud fire-place, usually in the open air. Here the water is made to boil, the liquor as it becomes thick and strong being decanted into another vessel, in which the evaporation is continued until the extract is sufficiently inspissated, when it is poured into moulds made of clay, or of leaves pinned together in the shape of cups, or in some districts on to a mat covered with the ashes of burnt cow-dung, the drying in each case being completed by exposure to the sun and air. The product is a dark-brown extract, which is the usual form in which cutch is known in Europe.

In Kumaon, N. India, a slight modification of the process affords a drug of very different appearance. Instead of evaporating the decoction to the condition of an extract, the inspissation is stopped at a certain point, and the liquor is allowed to cool, coagulate, and crystallize over twigs and leaves thrown into the pots for the purpose. By this method is obtained from each pot about 2 lb. of *kath* or catechu, of an ashy-whitish appearance. In Burma, the manufacture and export of cutch form one of the most important items of forest revenue. The quantity of cutch exported from the province in 1869–70 was 10,782 tons, valued at 193,602*l.*, of which, nearly half was the produce of manufactories situated in British territory. The article is imported in mats, bags, and boxes, often enveloped in the large leaf of *Dipterocarpus tuberculatus.* It is brought down from Berar and Nepal to Calcutta. That of Pegu has a high reputation.

Our imports of cutch in 1880 were 5155 tons, value 173,040*l.*, from the British E. Indies; 539 tons, 15,572*l.*, from other countries; total, 5694 tons, 188,612*l.* Our exports in the same year were :—892 tons, 28,527*l.*, to Germany; 676 tons, 24,562*l.*, to the United States; 478 tons, 15,505*l.*, to France; 303 tons, 10,537*l.*, to Holland; 177 tons, 5859*l.*, to Russia; 141 tons, 4835*l.*, to Belgium; 245 tons, 8719*l.*, to other countries; total, 2912 tons, 98,544*l.* The approximate London market value of Pegu cutch is 21–42*s.* a cwt.

An astringent extract prepared from the *Areca Catechu* (see Nuts—Areca, p. 1351) is said to contribute to commercial cutch; if so, it is a totally distinct product from those just described.

Divi-divi, or Libi-dibi.—These names are applied to the seed-pods of *Cæsalpinia coriaria*, a tree of 20–30 ft., indigenous to several of the W. Indies, Mexico, Venezuela, and N. Brazil, and naturalized in Madras and Bombay Presidencies, and in the N.-W. Provinces. The pod may be known by its drying to the shape of a letter **S**; it contains 30–50 per cent. of a peculiar tannin, somewhat similar to that of valonia. It is cheap, and may be used in admixture with barks; but it is dangerously liable to undergo fermentation, suddenly staining the leather a dark-red colour, and is therefore not in extensive use. The imports of it are mainly from Maracaibo, Parniba, and St. Domingo. Maracaibo, in 1880, exported 197,674 lb. of divi-divi, value 3222¼ dol. (of 4*s.* 2*d.*), to New York. Our imports of divi-divi into Liverpool, according to figures kindly furnished by Haw and Co., were 2200 tons in 1877, 1740 in 1878, 2132 in 1879, and 780 in 1880. The approximate market value is 12–17*l.* a-ton.

Galls.—The generic term "gall" is applied to those excrescences on plants which are produced by the punctures of insects, for the purpose of depositing their eggs. The excrescences are usually considered to be a diseased condition of vegetable tissue, resulting from the injection of some secretion of the insects. But this has been combated by A. S. Wilson, of Aberdeen, who considers that all insect galls are in reality leaf-buds, or fruit-buds, and not mere amorphous excrescences. The vascular lines which would form leaves can easily be followed up in the structure of the oak-leaf galls. And in cases where the egg has been deposited in the tissue of a young branch, the cap of the gall is sometimes surmounted by a leaf 2–3 in. long. But in the large blue Turkish galls, many lacunæ occur where the fleshified leaves have not filled up the spaces between them. If a dissection be made of one of the weevil-galls on the bulb of the turnip, the second or third slice will show the outer foliations, exactly similar to those of the root-buds. When the centre has been reached, where the maggot will be found, there will also be a vascular pencil running up from a medullary ray in the bulb, and bearing on its top a bud of the same description as that produced by a ray running out from a root. The insertion of the ovipositor brings a medullary ray into action, producing a tuberculated bud, and it is only the bud which the larva feeds upon. The growth of a bud is an intelligible cause of the growth of a gall, but nothing can be inferred from the injection of a fluid. The analogy to leaves is further shown by the fact that various microscopic fungi are matured in the interior of imperforate galls.

The principal commercial kinds of gall are oak-galls and Chinese galls.

Oak-galls, Nut-galls, Aleppo or Turkey galls (Fr., *Noix de Galle, Galle d'Alep*; Ger., *Levantische* or *Aleppische Gallen, Galläpfel*).—These are formed by the punctures of *Cynips* [*Diplolepis*] *Gallæ tinctoriæ* on *Quercus lusitanica* var. *infectoria* [*Q. infectoria*], a shrubby tree of Greece, Cyprus, Asia Minor, and Syria, and probably other varieties and even species of oak. The female insect is furnished with a delicate ovipositor, by means of which she pierces the tender shoots of the tree, and lays her eggs therein. In the centre of the full-grown gall, the larva is hatched and undergoes its transformations, finally (in 5–6 months) becoming a winged insect, and boring for itself a cylindrical exit-hole. The best commercial galls are those which have been gathered while the insect is still in the larval state. Such have a dark olive-green colour, and are comparatively heavy; but after the fly has escaped, they become yellowish-brown in hue, and lighter. Hence they are distinguished in the London market as "blue" or "green," and "white." In Smyrna, they are classified as "white," "green," and "black," the first two sorts generally fetching nearly the same price, while the black obtain considerably more, the approximate quotations being:—white and green, per Turkish *oke* (of 2·83 lb.), 8½–9 *piastres* (of 2*d.*); black, 13½–14 *piastres.* The "nuts" come mostly from Melemen, Cassaba, and Magnesia, also from the Syrian coasts, being plentiful on the east of the river Jordan, and are chiefly forwarded to France, England, and Salonica. The triennial yield is said to be invariably the best. They begin to reach Smyrna from the interior towards the end of July. The crop of 1880 was estimated at over 50,000 *okes.* The province of Aleppo, which used to afford 10,000–12,000 *quintals* (of 2 cwt.) annually, only exported 3000 in 1871. The galls collected in the Kurdistan mountains are marketed at Diarbekir, and sent thence to Trebizonde for shipment. Bussora, Bagdad, and Bushire also export considerable quantities.

The exports from Aleppo (including yellow berries, see p. 864) in 1880 were:—60 tons, 3600*l.*, to Great Britain; 322 tons, 19,320*l.*, France; 15 tons, 900*l.*, Italy; 44 tons, 2640*l.*, Austria, 55 tons, 3300*l.*, Turkey; 30 tons, 1800*l.*, Egypt; total, 526 tons, 31,560*l.* In 1878, the figures were 673 tons, 38,400*l.* Alexandretta exported in 1879 (including yellow berries):—41 tons, 2460*l.*, to England; 299 tons, 17,940*l.*, France; 20 tons, 1200*l.*, Italy; 25 tons, 1500*l.*, Austria; 87 tons, 5220*l.*, Turkey; 6 tons, 360*l.*, Egypt; total, 478 tons, 28,680*l.* The shipments from Trebizonde by steamer in 1880 were (from Turkey):—47 sacks (of 2 cwt.), 188*l.*, to Turkey; 240 sacks, 960*l.*, Great Britain; 264 sacks, 1056*l.*, France; 103 sacks, 412*l.*, Austria and Germany; 26 sacks, 104*l.*, Greece; total, 680 sacks, 2720*l.*; (from Persia): 25 sacks, 100*l.*, Great Britain; 31 sacks, 124*l.*, France; 30 sacks, 120*l.*, Austria and Germany; total, 86 sacks, 344*l.* Bushire despatched 5000*r.* worth to India in 1879. Syra sent 248*l.* worth to Great Britain in 1879. Venice exported 1745 tons of galls and bark, value 34,906*l.*, in 1879.

The best oak-galls contain 60–70 per cent. of tannic or gallotannic acid, and 3 per cent. of gallic acid. "Rove" is a small crushed gall, containing 24–34 per cent. of gallotannic acid. There are many other varieties of non-commercial oak-gall.

Chinese or Japanese Galls.—These are vesicular protuberances formed on the leaf-stalks and branches of the *Rhus semialata* [*Bucki-amela*], a tree of 30–40 ft., common in N. India, China, and Japan, ascending the outer Himálaya and the Khasia Hills to 2500–6000 ft., by punctures of the female of *Aphis chinensis*. The galls are collected when their green colour is changing to yellow, and are then scalded. They are light and hollow, 1–2½ in. long, and of very varied and irregular form. The Japanese are the smaller and paler, and usually more esteemed. The galls contain about 70 per cent. of tannic or gallo-tannic acid, and 4 per cent. of another tannin. They are consumed mainly in Germany, for the manufacture of tannic acid.

Hankow exported 30,949 *piculs* (of 133⅓ lb.) in 1872; and 21,611 *piculs*, value 136,214 *taels* (of about 6*s.*), in 1874. In 1877, the total Chinese export did not exceed 17,515 *piculs*. Hankow exported 24,742½ *piculs* in 1878, and 28,392 *piculs*, 59,614*l.*, in 1879; Pakhoi, 62*l.* worth in 1879; Canton, 3155⅓ *piculs* in 1877, 1939 in 1878, 3163½ in 1879; Ichang, 100½ *piculs*, 132*l.*, in 1878, 402½ *piculs*, 586*l*, in 1879; Shanghae, 27,659½ *piculs* in 1879.

In China trade returns, they are always miscalled "nut-galls" or "gall-nuts": correctly, they are *wu-pei-tze*. Oak-galls are exported from China resembling those of W. Asia. Japanese galls, *kifushi*, are sent in increasing quantities from Hiogo.

Our imports of galls in 1880 were:—24,590 cwt., 68,697*l.*, from China; 17,311 cwt., 60,648*l.*, from Turkey; 9182 cwt., 9013*l.*, from other countries: total, 51,083 cwt., 138,358*l.* Our re-exports in the same year were:—6260 cwt., 18,479*l.*, to Holland; 6022 cwt., 18,147*l.*, to Germany; 3214 cwt., 11,002*l.*, to France; 3045 cwt., 8598*l.*, to Belgium; 2651 cwt., 11,004*l.*, to the United States; 1625 cwt., 5205*l.*, to other countries; total, 22,817 cwt., 72,435*l.* The approximate London market values of galls are:—Bussora, blue, 82–102*s.* a cwt.; do., white and in sorts, 50-90*s.*; China, 50–70*s.*; Japan, 55–56*s.*

Gambier, Pale Catechu, or Terra Japonica (Fr., *Gambir*, *Cachou jaune*; Ger., *Gambir*).—These names are conferred upon an extract from the leaves of *Uncaria Gambier* [*Nauclea Gambir*] and *U. acida*, containing 36–40 per cent. of a brown tannin, which rapidly penetrates leather, and tends to swell it, but alone gives a soft porous tannage; it is largely used in conjunction with other materials for tanning both dressing- and sole-leather. The plants are stout climbing shrubs, the first-named being a native of the countries bordering the Straits of Malacca, and especially the islands at the E. end, though apparently not indigenous to any of the islands of the volcanic band, growing also in Ceylon, where no use is made of it; while the second, probably a mere variety, flourishes in the Malay islands.

The shrubs are cultivated in plantations, often formed in jungle clearings; the soil is very rapidly exhausted, and further injured by excessive growth of the ineradicable *lalang*-grass (*Andropogon caricosus*). It is found advantageous to combine pepper-culture (see pp. 1812–4) with that of gambier, the boiled leaves of the latter forming excellent manure for the former. The gambier-plants are allowed to grow 8–10 ft. high, and as their foliage is always in season, each plant is stripped 3 or 4 times in the year. The tools and apparatus for the manufacture of the extract are of the most primitive description. A shallow cast-iron pan about 3 ft. across is built into an earthen fire-place. Water is poured into the pan, a fire is kindled, and the leaves and young shoots, freshly plucked, are scattered in, and boiled for about an hour. At the end of this time, they are thrown on to a capacious sloping trough, the lower end of which projects into the pan, and are squeezed with the hand so that the absorbed liquor may run back into the boiler. The decoction is then evaporated to the consistence of a thin syrup, and baled out into buckets, When sufficiently cool, it is subjected to curious treatment: instead of simply stirring it round, the workman pushes a stick of soft wood in a sloping direction into each bucket; and, placing two such buckets before him, he works a stick up and down in each. The liquid thickens round the stick, and, the thickened portion being constantly rubbed off, while at the same time the whole is in motion, it gradually sets into a mass, a result which, it is said, would never be produced by simple stirring: it is reasonable to suppose that this manner of treating the liquor favours the crystallization of the catechin in a more concrete form than it might otherwise assume. The thickened mass, resembling soft yellowish clay, is now placed in shallow square boxes; when somewhat hardened, it is cut into cubes, and dried in the shade. The leaves are boiled a second time, and finally washed in water, which is saved for another operation.

A second plan is as follows:—The leaves are boiled, and bruised in a wooden mortar (*lesong*), from which they are put into a kind of basket of rattan open-work, which is pressed by a long piece of wood acting as a lever; the liquid is received into a trough, and there allowed to settle. When the sediment has acquired sufficient substance, it is put into a *kulit-kayo*, formed like a tub without a bottom, which lets the superfluous water drain off; when that is done, it is taken out, made into small cakes, and dried for use. A plantation employing 5 labourers contains 70,000–80,000 shrubs, and yields 40–50 *catties* (of 1⅓ lb.) of gambier daily.

Plantations were commenced in Singapore in 1829, and once numbered 800; but owing to scarcity of fuel, abundance of which is essential to the manufacture, and dearness of labour, the culture was fast declining in 1866. In 1872, it had much recovered. It is largely pursued on the mainland (Johore), and in the Rhio-Lingga Archipelago, S.-E. of Singapore; on Bintang, the most northerly of the group, there were 1250 plantations of it in 1854. None is cultivated in Sarawak, though found wild in many parts; the foreign export from Sarawak in 1879 had a total value of 88,148 dol. The best kind is brought largely from Sumatra, but is often adulterated with sago. The Rhio product is also thus sophisticated, and rendered heavier by the Chinese purposely packing it in baskets lined with wet *cajangs*, occasioning a loss to the purchaser of about 30 per cent.

Singapore is the great emporium for gambier, and exported 34,248 tons in 1871, 19,550 tons having been imported, chiefly from Rhio and the Malay Peninsula. In 1876, the export increased to over 50,000 tons of pressed block, and 2700 tons of cubes. In 1877, it fell to 39,117 tons, owing to differences with the Chinese dealers concerning adulteration; of this quantity, 21,607 tons were for London, 7572 for Liverpool, and 2345 for Marseilles. The United Kingdom imports in 1872 were 21,155 tons, 451,737*l.*, almost all from the Straits Settlements; in 1880, they were 26,061 tons, 461,781*l.*, from the Straits, and 352 tons, 6468*l.*, from other countries; total, 26,413 tons, 468,249*l.* Our re-exports in 1880 were:—2487 tons, 48,507*l.*, to Holland; 1591 tons, 31,542*l.*, to Germany; 1137 tons, 23,694*l.*, to Russia; 594 tons, 12,026*l.*, to other countries; total, 5809 tons, 115,769*l.* The approximate London market values are 15*s.* 6*d.*–21*s.* 6*d.* a cwt. for block, 18–24*s.* for pressed cubes, and 23–27*s.* for free cubes.

Hemlock.—The bark of the hemlock or hemlock spruce (*Abies canadensis*), of Canada and the United States, contains nearly 14 per cent. of tannin. The stripping of the bark commences in the southern parts of the United States in spring, and lasts during April–May; in New York, Michigan, and Wisconsin, the season is June–July; and further north, it is still later. It is said that the best product is obtained furthest south. The destruction of the hemlock forests is fast approaching. Within the last 25 years, the preparation of an extract from the bark, containing 18–25 per cent. of a deep-red tannin, giving considerable weight and firmness to leather, has superseded the export of crude bark. The mode of preparing the extract is as follows:—The bark in pieces ½–1 in. thick, and several inches long, is soaked for about 15 minutes in water at 93° (200° F.); it is then fed into a hopper, which conducts it to a 3-roller machine, something like a sugar-cane mill (see p. 1873), through which it passes, coming out lacerated and compressed; it next falls into a vat of hot water, where it is agitated by a wheel, that the tannin from the crushed cells may be dissolved in the water; hence it is raised by a series of buckets on an endless chain, somewhat in the manner of a grain-elevator, to another hopper, whence it is fed to another 3-roller mill; here it receives its final compression, and comes out in flakes or sheets, like coarse paper, and almost free from tannin. The buckets are made of coarse wire, that the water may drip through during the elevation. In order to avoid the blackening action of iron, wherever this metal is brought into contact with the solutions it is thickly coated with zinc. The solution is evaporated to a solid consistency, generally by vacuum-pans. About 2 tons of bark are represented by 1 bar. (of less than 500 lb.) of extract. The chief makers are A. S. Thomas, Elmira, N.Y.; S. Brown & Co., New York; Canada Tanning Extract Co., St. Leonard and Bulstrode; J. Miller & Co., Millerton, New Brunswick. The total production is probably over 10,000 tons annually, ranging in value between 17*l.* and 23*l.* a ton. Our imports are included in barks and extracts, p. 1988.

Kino.—See Resinous and Gummy Substances, pp. 1667–8.

Mimosa- or Wattle-bark.—The bark of numerous species of *Acacia*, natives of Australia, contain considerable percentages of deep-red mimo-tannic acid, which forms a hard and heavy tannage if used strong, though soft upper-leathers may be tanned with it in weak liquors. The chief kinds are as follows:—The common wattle (*Acacia decurrens*), including its variety *A. mollissima*, is known also under the names of green, black, and feathery, but must not be confounded with the silver wattle (*A. dealbata*), though but doubtfully a distinct species. The bark is obtainable in vast abundance, and is much used by tanners. The trees are stripped in September and the two or three months following, and the bark, being allowed to dry, is then in a marketable condition. This tree, which grows in the uplands, affords a larger percentage of tannin than the silver wattle.

Blackwood or lightwood (*A. melanoxylon*) yields tanners' bark, which is inferior, however, to that from *A. decurrens*. The bark of *A. penninervis* yields of tannic acid 17·9 per cent., and of gallic acid 3·8 per cent. The bark of the native hickory (*A. suppurosa*) yields of tannic acid 6·6 per cent., and of gallic acid 1·2 per cent.

The bark of *A. saligna*, of S.-W. Australia, is much used by tanners, as it contains nearly 30 per cent. of mimo-tannin. *A. harpophylla*, of S. Queensland, furnishes a considerable share of the mercantile wattle-bark for tanning purposes. The bark of *A. lophantha* contains only about 8 per cent. of tannin.

The broad-leaved or golden wattle (*A. pycnantha*), of Victoria and S. Australia, deserves extensive cultivation. It is of rapid growth, will succeed even in sandy tracts, and yields seed copiously, which germinates with the greatest ease. The perfectly-dried bark contains about 25 per cent. of tannin. The aqueous infusion of the bark can be reduced by boiling to a dry extract, which in medicinal and other respects is equal to the best Indian cutch. It yields approximately 30 per cent. of tannin, about half of which, or more, is mimo-tannic acid. Probably no other tanning plants give so quick a return in cultivation as the *A. pycnantha* and *A. decurrens* of Australia. The latter varies in its proportions of tannin from 8 to 33 per cent. In the mercantile bark, the percentage is somewhat less, according to the state of its dryness, it retaining about 10 per cent. of moisture. The bark of the silver wattle (*A. dealbata*) is of less value, often even fetching only half the price of that of the black wattle. The bark improves by age and desiccation, and yields 40 per cent. of tannin, rather more than half of which is tannic acid.

Amongst all the kinds, the bark of the broad-leaved wattle is considered the most valuable, containing the greatest quantity of tannin; that of the silver wattle is not so valuable, being deficient in tannin; the black wattle is considered the most productive species; it can be barked at 8 years of age, and will produce 40–60 lb. dried bark, and full-grown trees will yield 100–150 lb. per tree.

The cultivation of wattles for commercial purposes has till now remained undeveloped; but no doubt, as soon as it is understood, the utilization of many acres of land lying waste, or which has already been exhausted and rendered unfit for the growth of cereals, will be effected by the cultivation of the wattle. It requires so little attention as to make it very profitable, and wattle-growing and grazing can be combined satisfactorily. After the first year, when the young trees in the plantation have reached the height of 3–4 ft., sheep can be turned in.

Wattles grow in almost any soil, even the poorest, but their growth is most rapid on loose sandy patches, or where the surface has been broken for agricultural purposes. When the soil is hard and firm, plough furrows should be made at a regular distance of 6–8 ft. apart, into which the seeds are dropped. The seed should be sown in May, having been previously soaked in hot water, a little below boiling temperature, in which they may be allowed to remain for a few hours. The seed should be dropped at an average distance of 1 ft. apart along the furrow, in which case, about 7200 seeds would suffice for one acre of land. The seed should not be covered with more than about ¼ in. of soil.

On loose sandy soil, it might even be unnecessary to break up the soil in any way: the furrows may be dispensed with, and the seed sown broadcast after the land is harrowed. After the plants have come up, they should be thinned so that they stand 6–8 ft. apart. When the young trees have attained the height of 3–4 ft., the lower branches should be pruned off, and every effort afterwards made to keep the stem straight and clear, in order to facilitate the stripping, and induce an increased yield of bark. It is advisable that the black and broad-leaved should be grown separately, as the black wattle, being of much larger and quicker growth, would oppress the slower-growing broad-leaved one. Care should be taken to replace every tree stripped by re-sowing, in order that there should be as little variation in the yield as possible. The months of September–December, in Victoria, are those in which the sap rises without intermission, and the bark is charged with tannin. Analysis proves that the bark from trees growing on limestone is greatly inferior in tannin to that obtained from other formations, differing 10–25 per cent.

The estimated expenditure on a wattle-bark plantation of 100 acres during 8 years is:—

	£	s.	d.
Rent of 100 acres for 8 years at 6*s*. per acre per annum	240	0	0
Ploughing 100 acres in drills 10 ft. apart	25	0	0
Sowing wattles and actual cultivation, including cost of seed	37	10	0
Supervision for 8 years (nominal), say 10*l*. per annum	80	0	0
Pruning the trees, taking off useless wood (necessary for 2 years), 10*s*. per annum	50	0	0
Incidental and unforeseen expenses	27	10	0
Interest on the whole amount expended during 8 years	240	0	0
	700	0	0
Actual cost of stripping and carting, as shown below	1515	0	0
	£2215	0	0

The receipts derivable from a wattle plantation of 100 acres, planted in the manner proposed, would be:—

	£	s.	d.
Each acre planted with wattles, 10 ft. apart, would carry 400 trees, and at end of 5th year trees would yield say 56 lb. matured bark: stripping only every 3rd tree, 332 trees would be obtained off 100 acres: this, at 4*l*. per ton, would give for 1st stripping	1332	0	0
In the 6th or following year, a similar number of trees would be stripped: the bark having increased in weight (say 14 lb.), the increased yield of 2nd stripping would be 400 tons at 4*l*. per ton ..	1600	0	0
In the 7th year, the remaining trees would be stripped, from which a still greater increase would be obtained, say 480 tons at 4*l*. per ton ..	1920	0	0
Total yield of bark..	4852	0	0
The cost of stripping would not exceed 15*s*. per ton, on account of the facilities presented by the regularity of the trees, while carting would represent another 10*s*. per ton: these combined charges would be 25*s*. per ton, and on 1215 tons, would be	1515	0	0
Leaving a clear profit on the 100 acres of	£2637	0	0

The exports of mimosa-bark in 1876 were 11,899 tons from Victoria, 4758 from S. Australia, and 1735 from Tasmania. Later returns are included in barks, p. 1988. Shanghai imported 7038 *piculs* (of 133⅓ lb.) in 1879. The approximate London market values of mimosa-bark are:—Ground, 6–13*l*. a ton; chopped, 5–12*l*.; long, 5*l*.–9*l*. 10*s*. A very superior extract has been made from this bark.

Myrobalans or Myrabolams.—The fruits of several species of *Terminalia* constitute the myrobalans of commerce; they are chiefly *T. Chebula* and *T. Bellerica*, natives of India, the former being a tree 40–50 ft. high, and esteemed for its timber also. The fruits contain 30–35 per cent. of gallotannic acid, producing a soft and porous tannage, and good samples giving a bright-yellow colour. The tannin exists in the pulp, and is absent from the very hard "stone." The dried fruits are known locally as *har*, *harra*, or *bahera*, and are used commonly for dyeing, but not for tanning.

Our imports of myrobalans in 1880 were:—238,151 cwt., 121,465*l*., from Bombay and Sind; 115,670 cwt., 51,339*l*., from Madras; 11,020 cwt., 4717*l*., from Bengal and Burma; 3520 cwt., 1402*l*., from other countries; total, 368,361 cwt., 178,923*l*. Our re-exports in 1880 were 8015 cwt., 4328*l*., to Germany; 16,127 cwt., 8515*l*., to other countries; total, 24,142 cwt., 12,843*l*. The approximate London market values of myrobalans are 7–14*s*. a cwt. for good, and 5–10*s*. for common. Shanghai imported 4403 *piculs* (of 133⅓ lb.) in 1879.

Oak-barks (Fr., *Écorces de Chêne*; Ger., *Eichenrinden*).—The barks of several species of oak have valuable tanning properties. They are chiefly:—The common oak (*Quercus Robur*), which is of even greater importance as a timber-tree (see Timber—Oak); the cork oak (*Q. Suber*), described at length under Cork (see pp. 722–9); the evergreen oak (*Q. Ilex*); and the American chestnut-oak (*Q. sessiliflora*). These barks are among the most esteemed tannins as regards quality of leather, but are incapable of giving much weight, and from their bulk are costly to handle, containing only 10–12 per cent. of tannin (quercitannic acid). They give a reddish fawn-coloured leather, and deposit a good deal of bloom, but yield no gallic acid. The barks of the cork-oak and evergreen oak from S. Europe, are stronger and darker-coloured than English bark. The American chestnut-oak contains a peculiar fluorescent principle like æsculin.

Our imports of unspecified barks for tanners' and dyers' use in 1880 were:—189,399 cwt., 101,108*l.*, from Australia; 123,302 cwt., 32,974*l.*, Belgium; 57,232 cwt., 20,988*l.*, United States; 22,100 cwt., 6030*l.*, Holland; 18,648 cwt., 3676*l.*, Italy; 16,151 cwt., 6972*l.*, Algeria; 22,669 cwt., 8838*l.*, other countries; total, 449,501 cwt., 180,586*l.* Our imports of unenumerated bark-extracts in the same year were valued at:—516,578*l.* from Holland, 92,654*l.* France, 30,187*l.* United States, 16,315*l.* British N. America, 12,796*l.* Belgium, 13,769*l.* other countries; total, 682,299*l.* Our re-exports of barks in 1880 were:—19,548 cwt., 10,348*l.*, to Germany; 14,627 cwt., 7425*l.*, France; 4555 cwt., 3041*l.*, Holland; 10,304 cwt., 6080*l.*, other countries; total, 49,034 cwt., 26,894*l.*

With regard to cork-tree bark, James Gordon & Co., Liverpool, obligingly write that very little comes to England, the great bulk going direct to Ireland, where the consumption is large. The imports at Liverpool in 1880 were 186 tons, average value 8*l.* per ton. Of oak-bark, Hungary, in 1877, produced 25,000 tons, of which, 20,000 were exported to Germany for tanning purposes. The approximate London market values of oak-bark are:—English, 12–16*l.* per load of 45 cwt.; Foreign, tree, 5–8*l.* a ton; ditto, coppice, 6–8*l.* In 1879, Algiers exported 12,660,047 *kilo.* (of 2·2 lb.) of tanning bark.

Quebracho.—The local name *quebracho*, contracted from *quebra-hacho* ("axe-breaker"), is applied to several S. American trees possessing hard wood, belonging to distinct genera. They are chiefly as follows:—(1) *Aspidosperma Quebracho*, the *quebracho blanco*, a tree growing in the province of Catamarca, Argentine Republic; (2) *Loxopterygium* [*Quebrachia*] *Lorentzii*, the *quebracho colorado*, most prevalent in the province of Corrientes, the wood and bark of which come largely into commerce as tanning materials; (3) *Iodina rhombifolia*, the *quebracho flojo*, whose wood and bark are mixed with those of No. 2; (4) *Machærium fertile* [*Tipuana speciosa*], the *tipa*, which affords both wood and bark of less tanning value than No. 2. It would seem that the wood and bark of No. 2 are by far the most largely employed, containing 15–23 per cent. of a bright-red tannin. The wood and an extract from it are imported into Europe.

From information kindly furnished by James Gordon & Co., and Haw & Co., of Liverpool, it appears that the imports of quebracho-wood into Liverpool in 1880 were 200 tons, value about 4*l.* 10*s.* a ton; and of quebracho-bark, about 20 tons, none of which had been sold.

Sumach or Shumac (Fr., *Sumac*; Ger., *Gerbersumach, Schmack*).—The commercial term "sumach" is applied to the dried leaves of a number of S. European and American tannin-yielding plants. These are chiefly as follows:—In Sicily, the European or tanning-sumach (*Rhus Coriaria*); in Tuscany, *R. Coriaria*, often adulterated with leaves of *Pistacia lentiscus*; in Spain, several *Rhus spp.*, the products being divided into 3 kinds—Malaga or Priego, Malina, and Valladolid; in the Tyrol, the smoke-tree or fragrant or Venetian sumach (*R. Cotinus*); in France, *Coriaria myrtifolia*, divided into 4 sorts—*fauvis*, *douzère*, *redoul* or *redon*, and *pudis*, in Algeria, Tezera sumach (*R. pentaphylla*), used by the Arabs for making morocco-leather; in N. America, the smooth or white sumach (*R. glabra*), the Canadian sumach (*R. canadensis*), the staghorn sumach (*R. typhina*), and the dwarf or black sumach (*R. copallina*). These are found growing wild in the countries indicated, and are further subjected to cultivation in some districts, notably in Sicily. *R. glabra* and *R. copallina* are recommended chiefly for extended cultivation in the United States.

The soil usually chosen for cultivation of the plants is poor and light; but a much larger crop of leaves can be secured from strong, rich, deep soils, and it is generally admitted that the product in the latter case is also better. In Italy, limestone soils are considered to be especially suited to this culture, but the American varieties appear to be well adapted to sandy and clay soils as well. The primary requisite in a soil is that it should be well drained, the presence of stagnant water about the roots being exceedingly prejudicial. To prepare the soil for planting, it is ploughed as deeply as possible, and laid out in rows about 2 ft. apart. In Italy, small holes are made about 2 ft. long, 7 in. wide, and 5 in. deep, and a plant is inserted at each end. A more convenient method would consist in marking the field in shallow furrows in one direction 2 ft. apart, and then, with a heavy plough, tolerably deep furrows the same distance apart as, and at right angles to, the first. A plant may then be placed in the deep furrows at each intersection, the furrow again filled with the plough, and the earth pressed about the plant with the foot. If this were done in early spring-time, as soon as the earth is sufficiently dry to be conveniently worked, there can be no doubt that it would be successful, while it would certainly involve little cost. Plants are generally propagated from the young shoots which form each year about the base of an older plant, but may also be produced from cuttings made from young well-ripened wood, rooted by setting in a nursery or in frames, as in the propagation of grape-vines from cuttings. This latter method is scarcely ever required, however, when the cultivation has been started. Plants are also raised from seed, and seedlings are always found to be strong, vigorous, and thoroughly hardy; but on account of the greater time and labour involved in their production, this method of propagation has not received extended application. The first-mentioned generally gives the quickest, and probably most satisfactory results.

In selecting plants from any source, there are certain points to be observed:—(1) The shoots should come from young vigorous plants; (2) they should be over 1 ft. long; (3) those with large roots and few rootlets should be rejected; (4) those having white roots, covered with a fibrous, white, silky down, are also to be rejected, this being an indication of the presence of a very injurious subterranean parasitic fungus, capable of destroying the entire crop; (5) a good shoot is straight, at least ½ in. diam., 18 in. long, furnished with numerous buds close to each other, root short, but covered with rootlets. Shoots for planting may be collected in autumn, after the leaves have fallen, and be preserved in a nursery until spring; or this may be done in early spring, when the ground is very moist and soft. In either case, care should be observed that the rootlets are not injured by drying, or from any other cause.

The culture to be given the plant is somewhat similar to that required by Indian corn: the earth about it should be kept tolerably mellow and free from weeds, and such conditions can probably be maintained to a degree sufficient for sumach, by working several times during the growing season with a cultivator, and passing through the rows occasionally with a plough. All this work is not absolutely necessary to the life of the plant, but its vigour, and consequently its yield in leaves, may be considerably increased and strengthened thereby. After the first year, the number of operations may be diminished, but they should always be sufficient to keep the ground free from weeds and grass.

Shortly after planting, and when the plant is well set, the stock is pruned to a length of 6–8 in., when the plant is left to assume any form, and is no further pruned except by the process of collecting the leaves, unless hand-picking is resorted to; in such case, after the 2nd year, pruning takes place each year in the fall or winter, the plant being reduced to a height of 6–10 in. After the 3rd year, the plant begins to produce the shoots from about its base, already mentioned; these, if not needed for new plantations, should be removed each year, for if left to develop, they weaken the plant. If not removed during the summer, the operation should without fail be effected during the fall or winter.

The 1st crop of leaves may be secured during the year following that of planting. This develops and matures somewhat later than that from older plants, and in Italy it is not collected until the end of August or the 1st of September; but there are reasons for believing that in the United States, especially in the N. States, the collection of leaves from native varieties should be made much earlier, because the summer is much shorter, and the habits of the varieties grown differ from the Sicilian. All the leaves, except the young and tender ones of the extremities of the branches, are stripped off and placed in baskets, in which they are carried to a threshing-floor, where they are spread out in thin layers to dry. Here they must be frequently stirred and turned over, for which purpose a fork with wooden prongs is employed. In the fall, when grow this finished, and before the leaves have had time to become red, those remaining on the extremities are collected. To this end, the branches are broken just below the tuft of leaves, and the latter are allowed to remain suspended to the branch by a piece of bark not detached, and left in this condition until nearly or quite dry. They are then collected and treated in the same manner as other leaves, but the product obtained in this way is always of inferior quality.

After the 2nd year, crops of larger quantity and superior quality are obtained, and the collection is made in a different way, and much more frequently. The two methods followed in Sicily are (1) pruning, and (2) defoliation. The first, which is the more ancient, but much less costly, requires less care, and is simple and rapid; but it is injurious to the future condition of the plant, and the quantity of subsequent crops. The second, though slower, serves to better maintain the vigour of the plant, and the uniform quantity of the crop from year to year; in consequence, it reduces the necessity for frequent renewal of stocks.

Harvest by pruning is carried on in Italy as follows. During May, the lower leaves, which, from greater age, appear to have attained full maturity, and may be in danger of loss from falling, are removed in the same manner as described for collecting the leaves from yearling plants. Toward the end of June, and during the course of July, all branches bearing leaves are cut away, reducing the plant to the principal stock: by this means, the crop is harvested and the plant is pruned at the same time. But even in Sicily, the time for this operation is limited to no absolute period, and varies with the development of the leaf, as indicated by cessation of growth and increase in size. In this condition, also, the leaves will have acquired their deepest green colour, and attained their maximum weight and best quality. It is further stated that while this time varies according to locality, about Palermo it is never earlier than June nor later than July. The harvest by pruning must always be made by men accustomed to the work, and equal to the exertion required. Provided with a pruning-bill, they cut off all leaf-bearing branches, collecting them on the left arm, until each has cut as much as he can conveniently carry, when he places the armful on the ground with the butts in the direction of the prevailing wind, which, if tolerably strong, might carry away some of the leaves if turned in the opposite direction; finally, he presses down the branches with his foot, to make the heap more compact, and leave less surface exposed to the wind and sun. Another labourer deposits a second armful in the same place, presses it with his foot in like manner, and the two deposits constitute a bundle. At the close of the operation, there remain the young shoots which are formed about the base of the plant, the leaves of which are not fully developed, and consequently not fit for collection until at least 20 days later. After this time, they are removed by hand, care being observed not to injure the buds, especially if the shoots are to be used for stocks in the formation of plantations of the following year.

Defoliation, or collection by hand, is carried on whenever the leaf may be fully developed and ripe, beginning at first with the lower leaves, and continuing eventually to the ends of the branches. It takes place at 3 different times during the season: the 1st in May, the 2nd late in July or early August, and the 3rd in September. At the last collection, the extremities of the branches are broken down, and the leaves are allowed to dry before removal from the plant, as described under collections of the 2nd year. In the application of this method, the regular pruning is effected during the fall or winter, when the plant is dormant, and under such conditions the operation becomes a regenerative one, giving in this particular an advantage over the other method, in which the pruning is effected in the summer when the plant is in full vegetative activity, and so has a strongly deteriorating influence. In both methods of pruning, care should be observed to leave a long slanting section, upon which, water will be less likely to settle and promote decay.

The leaves collected by either method are dried in the open field where they have grown, and when dried, are carried to a threshing-floor to be beaten, or at once to the threshing-floor and dried there. In the former, the operation is rather more rapid, but there is greater danger of injury by rain, the effect of which is very deleterious, especially if it fall upon the leaves when they are partially dried. The damage resulting from this cause is less if the leaves are not lying upon the ground, and are so arranged that the air may circulate freely about and under them. In the pruning method, the leaves are dried upon the branches and in the heaps where they are first deposited. Sometimes they are turned, but generally it is considered better not to disturb them until completely dried, and ready for transportation to the threshing-floor. In this way, they are protected to a greater extent from the action of direct sunlight, which is said to be injurious to the quality of the product. When the leaves are collected by hand, they are dried upon the threshing-floor, where they are spread in thin layers, and stirred 3–4 times a day. They are then beaten with a flail to separate the leaves from the branches and stems. If this be done during the middle of the day, when the leaves are most thoroughly dry and consequently brittle, they are reduced to small particles, producing what is called "sumach for grinding." But if it be done in the morning, or on damp days, when the air is charged with moisture and the leaves are tough, they are separated from the stems more nearly entire and less broken, and the product obtained is called "sumach for baling." The stems remaining after the separation of sumach for baling still retain small particles of leaves attached to them, and they are therefore again beaten when perfectly dry for the production of a low-grade sumach, called by the Italians *gammuzza*. The products are classed as follows:—

Sumach for baling	relative market value		2·5
„ „ grinding	„	„	2·3
„ from yearling plants	„	„	1·5
„ „ ends of branches collected in autumn	„	„	1·0

To prepare these different grades for ultimate consumption, they are ground in mills similar to those employed for crushing olives, that is, in which two large stone wheels follow each other, revolving upon a circular bed, the whole construction being about the same as the Spanish or Mexican arrastre. The sumach thus pulverized is passed through bolting-screens, to separate the finer from the coarser particles.

In Virginia, the leaves are collected and cured by the country people, and sold and delivered to owners of mills for grinding. Their particular object being to secure the largest possible quantity of product at the lowest cost, little attention is given to the quality obtained, or the manner of collecting. The most intelligent dealers in the raw material urge upon collectors to observe the following particulars:—The leaf should be taken when full of sap, before it has turned red, has begun to wither, or has been effected by frost, to ensure a maximum value for tanning purposes. Either the leaf-bearing stems may be stripped off, or the entire stalk may be cut away, and the leaves upon it allowed to wither before being carried to the drying shed; but care must be observed that they are neither scorched nor bleached by the sun. When wilted, they are carried to a covered place, and spread upon open shelving or racks to dry, avoiding the deposit in any one place of a quantity so great as to endanger the quality of the product by overheating and fermentation. Sumach should be allowed to remain within the drying-house at least one month before sending to the market; in case of bad weather, a longer period may be required. When ready for packing for shipment, it should be perfectly dry and very brittle, otherwise it is likely to suffer injury in warehouses from heating and fermentation.

Buyers of sumach leaves for grinding depend largely upon colour for the determination of the value; the leaves should, therefore, when ready for market, present a bright-green colour, which is evidence that they have suffered neither from rain after being gathered, nor from heating during the process of drying. Leaves having a mouldy odour or appearance are rejected. The Virginian crop reaches 7000–8000 tons, and is collected at any time between July 1 and the appearance of frost.

There is an important difference in the value of the European and American products. The proportion of tannic acid in the latter exceeds that found in the former by 6–8 per cent., yet the former is much preferred by tanners and dyers. By using Sicilian sumach it is possible to make the finer white leathers, so much used for gloves and fancy shoes; while by the employment of the American product, the leather has a disagreeable yellow or dark colour, apparently due to a colouring matter, which, according to Loewe, consists of quercitrin and quercetin, and exists in larger quantity in the American than in the Sicilian.

The experimental results obtained by collecting sumach at different seasons were :—

Virginia, mixed,	collected in	June, gave	22·75	per cent. of tannic acid.
" "	"	July, "	27·38	" "
" *R. glabra*	"	August, "	23·56	" "
" *R. copallina*	"	" "	16·99	" "
Sicilian, *R. Coriaria*	"	" "	24·27	" "

It is evident, therefore, that in order to secure the maximum amount of tannic acid, the sumach should be collected in July, but the colouring matter of the leaves has an important influence upon the value of the product. The leaves of the upper extremities of the stalks are always richer in tannic acid than those of the base; and the increase of age of the plant is accompanied by a general diminution of this acid. Yet the collection of the crop should be delayed as long as possible, because the diminution of tannin in the leaves will be abundantly compensated for by the quality of the product.

Experiments upon the presence of colouring matters were made by treating gelatine solutions, and gave the following results :—

Virginia, mixed,	collected in	June, gave	.. A nearly white precipitate.
" "	"	July, "	.. A decidedly yellowish-white precipitate.
" *R. copallina,*	"	August, "	.. A dirty-yellow precipitate.
" *R. glabra,*	"	" "	.. A very dirty-white precipitate.
Fredericksburg mixed,	"	" "	.. A dirty-yellow precipitate.
Sicilian	"	" "	.. A slightly yellowish-white precipitate.

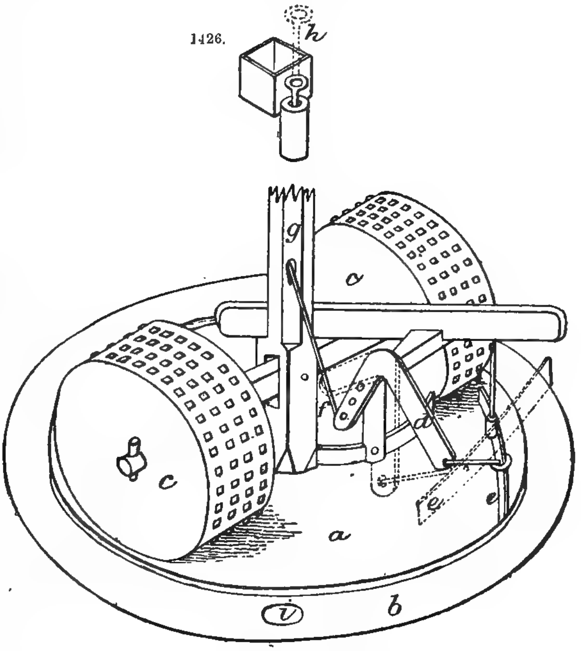
It is therefore advised that for the purpose of tanning white and delicately-coloured leathers, the collection should be made in June; while for tanning dark-coloured leathers, and for dyeing and calico-printing in dark colours, where the slightly yellow colour will have no injurious effect, the collection be made in July. It appears that for all purposes, the sumach collected after the 1st of August is inferior in quality.

Fig. 1426 shows a mill for grinding sumach-leaves; it consists of a heavy solid circular wooden bed *a*, 15 ft. diam., with a depression around the edge *b*, a few inches deep and 1 ft. wide, for the reception of the ground sumach from the bed, and 2 edge-rollers *c*, weighing about 2500 lb. each, 5–6 ft. diam., and provided with numerous teeth of iron or wood, thickly inserted. Most mills have to be stopped to allow the unloading of the bed, but this delay is obviated by an apparatus consisting of an angular arm *d*, attached to a scraper *e*, and worked by a lever *f*, which passes through the hollow shaft *g* and extends to the room above, where it terminates in a handle *h*. The scraper carries the ground sumach to the opening *i*, whence it is taken by an elevator to a revolving sieve or screen in a room above. After screening, the sumach is packed in bags, 15 to the ton, being always sold by that weight. The chasers and beds are inclosed in a case or drum, and the grinding is done by the application of power to the upright shaft *g*. The mills are fed from above. The packing is sometimes done by machinery alone. The best mills cost about 600*l*. In Europe, and in some parts of the S. States, sumach is still ground by stones revolving on a stone bed, and the sifting is often done by hand.

E. Coez & Co., St. Denis, near Paris, make a sumach extract. It is concentrated to a syrupy consistence in a vacuum-pan, and keeps well, exhibiting none of the acidity which is manifested by a simple decoction of sumach leaves. Sumach contains 16–24 per cent. of gallotannic acid, and is somewhat similar in tanning properties to myrobalans, but paler in colour. It is principally used for tanning morocco and other fancy leathers.

The district of Ancona yields 200 tons per annum of sumach, said to be equal to and cheaper than the Sicilian, but mostly consumed locally. Palermo exported of " ventilated " sumach to the United States 120,043 bags (14 = 1 ton) in 1877, and 50,085 in 1878, the average value being 14*l.* a ton. Trieste exported 7800 cwt. by land in 1877; in 1878, the shipments to England were 16,600 *kilo.* (of 2·2 lb.), value 1328 fl. (of 2*s.*), and in 1880, 91,800 *kilo.*, 7344 fl. Rustchuk in 1880 exported 1400 tons, chiefly to Roumania and Austria. Our imports in 1880 were 10,573 tons, 133,249*l.*, from Italy, and 1047 tons, 12,416*l.*, from other countries; total, 11,620 tons, 145,665*l.* The approximate London market value is 15*s.*–16*s.* 6*d.* a cwt. for Sicilian, 10–11*s.* for Spanish.

1426.



Valonia (Fr., *Vélanèdes*; Ger., *Valonia*). This is the commercial name for the large pericarps or acorn-cups of several species or varieties of oak, chiefly *Quercus Ægilops* and *Q. macrolepis.* The former is found growing in the highlands of the Morea, Roumelia, the Greek Archipelago, Asia Minor, and Palestine; the latter constitutes vast forests in many parts of Greece, and especially on the lower slopes of Taygetos, towards Ætylon and Mani (Laconia). Prof. Orphanides, of Athens, alludes to a third species or variety called *porto galussa*, which yields a superior kind of valonia, and named by him *Q. stenophylla.* The chief localities of production in Asia Minor are Ushak, Borlo, Demirdji, Ghiördes, Adala, Nazlü, Buldur, Sokia, Balat, Troja, Aivalik, and Mytilene. The annual exports, mainly from Smyrna, reach 600,000 *quintals* (of 2 cwt.), value about 400,000*l.* In Greece, the production is chiefly centred in the following districts: (1) The province of Lacedemonia, which afforded 10,000 cwt. in 1872; (2) the province of Gythium, in the lower part of Mount Taygetos, which gave 60,000 cwt. in 1872; (3) the island of Zea, which formerly yielded 30,000-40,000 cwt., lately reduced to 15,000 cwt. yearly; (4) Attica, especially the neighbourhood of Cacossalessi, grows 3000-5000 cwt., shipped from Oropos, in the Strait of Chalcis; (5) the island of Eubœa, whence about 1000 cwt. are shipped annually at Bouffalo; (6) the province of Triphyllia raises 3000 cwt., which go to Trieste, viâ Cyparissie; (7) the province of Pulos, especially the commune of Ligudista, grows over 2000 cwt., despatched from Navarino to Trieste; (8) the province of Achaia has a yearly crop of 30,000–40,000 cwt., shipped to Trieste from Courupeli and Caravostassi, between Patras and Cape Papa; (9) the small towns of Anatolico and Astakos (Dragomestre) collect the valonia of the eastern parts of Ætylon, Acarnania, and Cravassaras (a port in the Gulf of Arta), and of all the other western parts, to be sent to Trieste for shipment to England and Italy. Ætolia and Acarnania furnish abundant crops, that of 1872 exceeding 100,000 cwt. The total area of the Greek valonia-yielding forests is said to be about 13,000 *stremme* (of 119½ sq. yd.). The total production in 1877 was estimated at 2,601,000 *quintals* (of 2 cwt.); the greater part is exported, about ⅗ going to Austria, and the rest to Italy and England. The proportions of tannic acid in the valonia from different districts of Greece are said to vary as follows: Patras, 19–28½ per cent.; Gythium, 27¼–35½; Zea, 12¼–25¼; Vonitza, 18–20.

In Turkey, the fruit ripens in July–August, when the trees are beaten, and the fallen acorns left on the ground to dry. The natives afterwards gather them, and transport them on camel-back to stores in the towns, whence they go by camel and train to Smyrna, and are there placed in heaps 5-6 ft. deep in large airy stores for some weeks, during which the mass heats, and the acorn itself, which contains but little tannin, and is used for feeding pigs, contracts and falls from the cup. This incipient fermentation is attended with considerable risk; if carried too far, a large proportion of the valonia becomes dark-coloured and otherwise damaged. When ready for shipment, the heaps are hand-picked, the best being reserved for the Austrian market (Trieste); and the rest going to

England. In some cases, the rubbish having been removed, the remainder is known as "natural," and is thus exported to England.

In Greek commerce, three qualities are distinguished, *chamada*, *rhabdisto*, and *charchala*. The *chamada* (*camata* and *camatina* of Asia Minor) is the best; it is collected in April, before the acorn is matured, hence the cup which encloses the acorn is small and incompletely developed. The *rhabdisto* is the second quality; it is collected in September–October, and is distinguished by the fruit being larger and riper; the name means "beaten," the fruits being beaten down from the trees with sticks. After mid-October the collection ceases, because the first rains cause the fallen fruit to ferment or turn black, and they then take the name of *charchala*. They are distinguished by the cups being completely open, and containing no acorns. They are considered much inferior, possessing little tannin.

Sometimes the acorn cup is attacked by a kind of honey-dew, which deposits on the cup, and makes it very liable to heat when gathered, the cup becoming very dark and deficient in tannin. The Turkish crop of 1875 was much damaged from this cause, many parcels reaching England in an unsaleable condition. The cause of the disease is yet unknown; it seems specially prevalent when the crop is large and the acorn fully developed. A good sample of valonia should be composed of medium-sized cups, with the rim or wall very thick, and the exterior spines small and uniform. The cut or broken cup should show a bright-drab fractured surface. Valonia contains 25–35 per cent. of a tannin somewhat resembling that of oak-bark, but giving a browner colour and heavier bloom. It makes a hard and heavy leather, and is generally used in admixture with oak-bark, myrobalans, or mimosa-bark.

The Greek crop in 1880 was much damaged by the cold spring: it gave 600 tons in Acarnania and Ætolia, 650 in Cape Papa, and 1400 in Mania; total, 2650 tons. Calamata and Messenia produced 115 tons, 1700*l.* Syra exported in 1879, 1174*l.* worth to Great Britain, 348*l.* Austria, 259*l.* Russia, 250*l.* Turkey, 178*l.* Egypt. Hungary exported 942 tons in 1880. Adana shipped 9450*l.* worth in 1878; and Dedeagatch, in the same year, 1,500,000 lb., 9000*l.* Musyna [Mersineh] sent 670 tons, 3350*l.*, to Italy, and 450 tons, 2250*l.*, to Austria, in 1879; and 480 tons, 2240*l.*, to Italy, and 128 tons, 640*l.*, to Greece, in 1880. Our imports in 1880 were:—From Turkey, 30,391 tons, 471,637*l.*; Greece, 2916 tons, 41,312*l.*; other countries, 466 tons, 7105*l.*; total, 33,773 tons, 520,054*l.* The approximate London market values are:—Smyrna, 12*s.* 6*d.*–20*s.* 6*d.* a cwt.; Camata, 15–19*s.*; Morea, 10*s.* 6*d.*–18*s.*

Miscellaneous.—Besides the foregoing tannins, which already occupy prominent places in European and American commerce, there are many others as yet of minor importance, but possessing qualities which may bring them into note in the near future. They are as follows:—

Abies Larix bark, the larch, contains 6–8 per cent. of a red tannin.

Acacia albicans fruits, the *hiusache* of Mexico, are used as substitutes for gall-nuts, costing locally about 5*d.* a lb. *A. arabica*, the *babul* of India, yields a tannin which gives a nearly pure-white precipitate with gelatine: the proportions are 12·55 per cent. in trunk-bark, 18·95 in branch-bark, 15·45 in twig-bark. The supply is unlimited. It works well with myrobalans. *A. Cebil*, the red cebil of the Argentine Republic, contains 10–15 per cent. of tannin in the bark, and 6–7 per cent. in the leaves; another variety, the white cebil, contains 8–12 per cent. in the bark, and 7–8 per cent. in the leaves. *A. Cavenia*, the *espinillo* of the Argentine Republic, has 33–4 per cent. of tannin in the fruit-husks. *A. penninervis* bark, the "hardy" acacia of Australia, contains 18 per cent. of tannic acid and 3–4 of gallic.

Alnus glutinosa bark, the common alder, contains about 16 per cent. of tannin.

Cæsalpinia Cacalaco fruits, the *cascalote* of Mexico, are very rich in tannic and gallic acids, and locally used for tanning.

Comptonia asplenifolia leaves, the sweet-fern of the United States, contain 9–10 per cent. of tannin.

Coriaria ruscifolia bark, the *tutu* of New Zealand, contains 16–17 per cent. of tannin.

Elæocarpus dentatus bark, the *kiri-hinau* of New Zealand, contains 21–22 per cent. of tannin. *E. Hookerianus* bark, the *pokako* of New Zealand, contains 9–10 per cent. of tannin.

Ephedra antisyphilitica, on the table-lands of Arizona and Utah, gives 11–12 per cent. of tannin.

Eucalyptus longifolia bark, the "woolly-butt" of Australia, contains 8·3 per cent. of tannic acid and 2·8 of gallic. The "peppermint" tree contains 20 per cent. of tannic acid in its bark. The "stringy-bark" (*E. obliqua*) gives 13½ per cent. of kinotannic acid. The Victorian "iron-bark" (*E. leucoxylon*) contains 22 per cent. of kinotannic acid, but is available only for inferior leather.

Eugenia Maire bark, the *whawhako* of New Zealand, contains 16–17 per cent. of tannin. *E. Smithii* bark, the "myrtle"-tree of Australia, contains 17 per cent. of tannic acid and 3–4 of gallic.

Fuchsia macrostemma root-bark is thin, brittle, and easily exhausted; it contains about 25 per cent. of a bright-red tannin, which has been successfully tried. It is the *churco* bark of Chili, which, however, is attributed by the Kew authorities to *Oxalis gigantea.*

Inga Feuillei pods, the *pay-pay* of Peru, contain 24 per cent. of an almost colourless tannin.

Laurus Peumo rind is used in Chili for tanning uppers.

Malpighia punicifolia bark, the *naucite*, or *manquitta* bark of Nicaragua, contains 20–30 per cent. of a very light-coloured tannin.

Persea Lingue bark is red-brown, soft, and easily exhausted by water; it contains 20–24 per cent. of tannin, and much slimy matter which promotes the swelling of the hides. It serves in S. America, especially in the Chilian province of Valdivia, for tanning Valdivia leather. In S. Chili, are enormous forests of the tree. The imported bark has given good results with heavy leathers.

Phyllocladus tricomanoides bark, the *kiri-toa-toa* of New Zealand, contains 23 per cent. of tannin.

Polygonum amphibium leaves, an annual plant abundant in the Missouri Valley, contain 18 per cent. of tannin, and can be mown and stacked like hay. It is largely used in Chicago tanneries, and said to give a leather which is tougher, more durable, of finer texture, and capable of higher polish, than that tanned with oak-bark.

Punica Granatum fruit-rind, the pomegranate, contains about 13·6 per cent. of a tannin like myrobalans, and a considerable quantity of starch; the tannin is greatest in the bitter kind, which is used for preparing morocco-leather; the root-bark also is rich in tannin.

Rhizophora Mangle bark, the mangrove, of Venezuela, contains 24–30 per cent. of deep-red tannin, if obtained from young stems; samples from the W. Indies have given 11·94 per cent., probably by the gelatine process; two samples from Shanghai, by Löwenthal's improved method, gave respectively 9·8 and 9·5 per cent. calculated as oak tannin, and 71·96 and 78·52 of woody fibre. Guayaquil exported 9328 cwt. of the bark to Peru in 1879.

Tecoma pentaphylla bark, the *roble colorado* of Venezuela, contains 27 per cent. of tannin, accompanied by a soluble orange-red colouring matter.

Wagatea spicata pods contain 15 per cent. of tannic acid. The plant, a scrambling shrub, is a native of the Concans.

Weinmannia racemosa bark, the *tawhero towai*, or *kamai* of New Zealand, contains 12–13 per cent. of tannin.

Bibliography.—J. G. Neubrand, 'Die Gerbrinde' (Frankfurt-a-M.: 1869); J. Wiesner, 'Die Rohstoffe de Pflanzenreiches' (Leipzig: 1873); 'Wattle Bark' (Rep. Board Inquiry, Melbourne: 1878); L. Wittmack, 'Die Nutzpflanzen aller Zonen' (Berlin: 1879); W. McMurtrie, 'Culture of Sumac, and preparation for market' (Dep. Agr. spec. rep. No. 26, Washington: 1880); A. Hansen, 'Die Quebracho-Rinde' (Berlin: 1880); R. J. Bernardin, 'Classification de 350 Matières Tannantes' (Gand: 1880); F. R. v. Höhnel, 'Die Gerberinden' (Berlin: 1880).

(See Acid—Gallic; Leather).

TEA (Fr., *Thé*; Ger., *Thee*).

The term "tea" is widely and vaguely applied to many plants (see pp. 2010–1), but is properly restricted to the numerous varieties derived by cultivation from two species of *Thea*, the Chinese (*T. chinensis* [*Camellia Thea*]) and the Assamese (*T. assamica*). As a result of long cultivation and promiscuous planting, there is scarcely a tea-garden but what is mainly filled with hybrids of all degrees between these two species. The Assam plant is vastly superior to the Chinese, and should be selected in all cases for rational culture. The seed of all is the same in appearance, and cannot be distinguished. It ripens about one year after the flower has faded. When picked in the shells, it is sunned for ½ hour daily for 2–3 days, "shelled," and spread to dry within a building. It should be sown as soon as possible after shelling: if kept for 2–3 weeks, it is best in layers under dry earth; if for longer, thinly spread on the drying-floor. It travels well in bags ⅓ filled, or in layers between charcoal in boxes. Its formation reduces the leaf-crop, and should be limited to actual needs. It furnishes a valuable oil (see p. 1411), not to be confounded with the essential oil of the leaves (see p. 1431). About 30,000 seeds are contained in 1 *maund* (of 80 lb.), of which about ⅔ may be expected to grow.

Cultivation. *Sowing.*—Seed is sometimes sown in nurseries, where they can be well tended; but this is costly, and the plants lose 3 months' growth when put out. Nurseries may be dispensed with where cool weather and spring rains are certain, but not otherwise. Nursery-beds are made in the poorest soil of the plantation, where watering is convenient. Artificial shade is essential. The beds are generally lower than the paths, to accumulate moisture, but may need to be above in some cases. The soil is loosened only to a slight depth, and the seed is sown in drills 6 in. apart, and the seeds 2–3 in. apart, if good. In the preparation of the ground, erection of shade, and general operations, there is little variation from the systems adopted with coffee (see pp. 691–8). The shade is removed gradually and piecemeal when the seedlings bear 4 leaves.

When nurseries are dispensed with, the seed is sown where the bushes are intended to remain (called sowing "at stake"). About 4 weeks previously, holes are dug 9 in. diam. and 12 in. deep, the soil being placed where it will not fall back; and these holes are filled up with surface soil (not that dug from them), with perhaps a handful of manure if the land is poor, and well pressed down for the reception of the seed. Two or three seeds are sown in this 6 in. apart, and gently pushed down about 1 in. The ground is then kept clean by hand-weeding, and lightened up at intervals by a *koorpee*. The best plant is left at each hole, the others being taken up and transplanted to vacancies.

Col. Money advocates another method of planting. The seed is put in layers alternating with mould, the seeds lying close together, and the earth covering them 2 in. deep. Each layer is examined every 3–4 days, and seeds which have burst are planted out root-side downwards. Only one seed need then be placed in each hole, as it is sure to grow; but great care is demanded in performing the operation.

Soil and Situation.—Tea grows on almost all soils, and flourishes on many. A light sandy loam is about the best, and the more humus there is on the surface the better; if 3 ft. deep, it matters little what the subsoil is, otherwise a mixture of sand and clay is desirable. Col. Money considers the light loam of Kumaon the best tea-soil in the world, being enriched with long accumulations of oak-leaves. Soil cannot be too rich for tea growing, provided it is sufficiently light and friable; the latter condition is absolutely essential, to permit the penetration of the spongioles (ends of the feeding-roots). Existing vegetation forms a pretty fair index of the fertility of the soil. Oak-bearing land is preferable to all others; but the removal of heavy forests adds much to the cost of taking in new land. Facilities for obtaining an abundant water-supply are quite indispensable; and the presence of means of water-carriage for conveying the crop to market materially adds to the advantages of the estate. Flat land is preferable to steep slopes; but the lower parts of slopes which are covered with jungle above are admirably adapted, as the vegetation diminishes the wash, and contributes rich fertilizing matters. Table-land cannot be too flat, but perfectly flat valleys are not eligible. Very narrow valleys are objectionable on all scores, and preference should be given to those which have a slope two ways. An adjacent stream for irrigation purposes is a great desideratum. Flat land always yields more heavily than slopes, as it admits of high cultivation. When planting on slopes, aspect is a primary consideration; it should be carefully chosen with a view of counteracting the extremes of climate: thus the coldest aspect will be the best in very hot climates, and *vice versâ*.

Forming a Tea-garden.—The first step will usually be to cut and burn the jungle, much in the same way as already described for coffee (see p. 692), a few large trees being left here and there (say 1 on every 2–3 acres) for sheltering the workmen, and shading picked leaf before it goes into house. Lining and holing are performed as in the case of coffee (see p. 693), the holes being 10 in. diam. and 15 in. deep. A garden of 100 acres is usually quite large enough to commence with. This should be divided into plots of 5–10 acres each, by means of paths or prominent stakes, the main object in view being to make separate sections for each portion of the crop that manifests any peculiarity in the number of its "flushes" or the quality of its leaves, many advantages arising from treating the crop in a piecemeal fashion, as the forwardness or backwardness of any section may require. Close planting is recommended by the best authorities, say 4–4½ ft. apart each way on flat ground, and 3½ ft. between the lines and 2 ft. apart in the lines when on slopes, to prevent wash. Close planting gives a greater number of bushes per acre, and keeps down weeds; but sufficient space must be left for digging between the bushes and picking the crop. Col. Money gives the following useful table showing the number of plants per acre, and the area covered by one lakh of seedlings, at the distances named:

Distances in ft.	Sq. ft. to each plant.	Plants in 1 acre.	Area in acres covered by 1 lakh of seedlings.	REMARKS.
6 by 6	36	1,210	82½	Too wide for any plants.
6 ,, 5	30	1,452	69	
6½ ,, 4	26	1,675	59¾	
5 ,, 5	25	1,742	57½	
6 ,, 4	24	1,815	55	
6 ,, 3½	21	2,074	48	For hybrids, but still rather too wide.
5 ,, 4	20	2,178	45½	
6 ,, 3	18	2,420	41¼	Good distances for hybrids.
4 ,, 4	16	2,722	36¾	
5 ,,. 3	15	2,904	34½	
4 ,, 3	12	3,630	27½	Chinese, for early return.
3½ ,, 3½	12¼	3,555	28	Chinese.
3½ .. 3	10½	4,148	24	
6 ,, 3¼	19½	2,233	44¾	Hybrid.
5 ,, 3¼	16¼	2,726	36¾	Chinese.
5 ,, 3½	17½	2,489	40	
3½ ,, 2	7	6,223	16	Best distance for Chinese on steep slopes.

On flat land, he advises—hybrid, if high-class, 4 × 3½ or 4½ × 4; Chinese, 3 × 3.

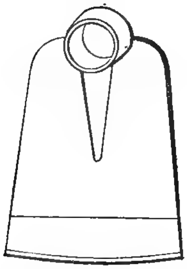
Planting.—About a fortnight before setting out the seedlings, they are "tipped" by pinching off the closed leaf at the head (see Fig. 1430), which makes them hardier. The removal of the seedlings is much facilitated by flooding the bed with water, as described for cinchona (p. 803), and similar care should be taken to have a good mass of soil around the roots. A good plan in taking up is to cut a trench below the bed, and then turn over line after line of seedlings by inserting a prong behind. The plants are carried in baskets to the garden, and there placed in little holes made with the hand or a narrow *kodalee* within the soft soil which has previously (p. 1994) been filled into the pit. The planting must be done so that the tap-root shall not turn up, that the rootlets shall preserve their lateral position, that the "collar" of the plant (where it issued from the ground in the nursery) shall be 1½ in. higher than the surrounding surface, and with so much pressure that the soil shall not cake about the plant, and shall be equally close at all depths. Cloudy and rainy days are the best for transplanting, but very wet weather is highly objectionable. In India, the operation is best performed by mid-June, and should not in any case extend beyond the end of July. Jeben has recently introduced some new tools for transporting and transplanting, which are highly approved of.

Cultivating and Pruning.—The soil overlying the roots of each plant should be repeatedly lightened up for the admission of air. This is best done by digging round the bushes with the *kodalee*, beginning at about 9 in. from the stem, and extending 2 ft. in all directions after the second year, taking care to use the blade of the tool so that it follows the line of the roots. A wide hoe is perhaps as useful a tool for this purpose. Till the plants are 1 year old, the soil for 6 in. round is only opened up about once a month with the *koorpee*. Weeds must be rigorously kept down, which is best done with a Dutch hoe. The weeds may be buried in trenches between the lines.

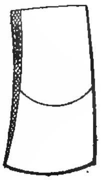
As it is only young wood and shoots that give leaf, pruning is essential to produce large crops. It must be done while the sap is down, and should be as soon as possible after the sap has gone down. It can only be performed in a rough and ready way, as the time is limited and the number of bushes to be treated is very great. Pruning-knives and hedge-bills, such as supplied by Brooker, Dore, & Co., London, are the best instruments. The same care in pruning the large branches must be exercised as with all other plants: the cut must be clean, sloping upwards, and not near enough to a bud to injure it. Such care cannot be taken with the numerous twigs. The plant should be induced to grow laterally, but not to exceed 4 ft. high. All branches less than 6 in. above ground should be pulled off downwards with a sharp tug. The centre of the bush must be opened out. No plant should be pruned for 18 months after transplanting, or the tap-root will not descend sufficiently. After that, all must be pruned, but some more than others. Two-year old plants over 2½ ft. high may be reduced to 20 in., and their thick wood to 11–18 in. It is better to prune too much than too little. The prunings are buried while green between the lines, and form good manure.

Other tools supplied by Brooker, Dore, & Co., to Indian tea estates are the solid *kodalee* (Fig. 1427), the cast-steel wedge-axe weighing 3 lb. and upwards (Fig. 1428), and the steeled Assam fork, with either 3 or 4 tines, weighing 4–5½ lb. (Fig. 1429).

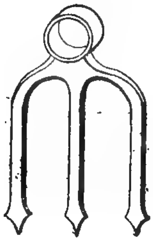
1427.



1428.



1429.



Filling up Vacancies.—Filling up the vacancies left by the failing of some plants is usually a hopeless undertaking in the case of tea, as the young seedlings get destroyed by the weeding, and are starved out by the surrounding mature plants, consequently Indian tea-gardens have 12–40 per cent. of their area wasted by vacancies. Jeben's transplanter may perhaps succeed in overcoming the difficulties encountered. Meantime Money recommends a plan of planting in pots and staking the young plants, which has answered well. Earthenware pots 7½ in. diam. and 7½ in. deep, with a 2-in. hole in the bottom, are filled with soil from the garden; 2 or 3 seeds are put into each near the centre and ½ in. below the surface; and the pots are placed near water and under artificial shade. When germinated, the best seedling is left in the pot to grow till the rains, being watered occasionally, and gradually deprived of shade. After the first rain, the pot is removed to a hole prepared at the vacancy; the bottom of the pot is knocked off, the sides are broken and partially removed, and the whole is planted and earth is filled in round. With care, the rootlets are not disturbed, and the growth is not checked for a day. Bamboo baskets do not give such good results. Money proposes to modify this plan so as to avoid destruction of the pots, as follows:—The pots are made larger, and provided with a tin lining about 1 in. less in diameter, the intervening space being filled with sand; the tin lining is then removed, and the layer of sand permits the subsequent extraction of the plant with mould caked around it without breaking the pot, which may thus be used indefinitely. A somewhat similar plan is adopted with cinchona (see p. 802).

Manures.—Judicious manuring nearly doubles the yield of tea, and at the same time improves its flavour and increases its strength. An excellent manure available on all tea-gardens consists of the prunings of the bushes themselves, and the weeds and general garden rubbish. Of animal manures, the best are nightsoil and bird-droppings, and the next best is cattle-manure; horse-dung is heating, and needs to be used with care. Artificial chemical manures will probably come into extensive demand, as they have done for coffee, sugar, and other tropical crops. One highly spoken of is known as Money and Ponder's, and is manufactured by J. Thompson, Kooshtea, Bengal.

Manure should be applied to each bush, by laying it in a trench 9 in. wide and 6 in. deep, dug all round the bush at a distance of 6–12 in. from the stem, according to age, and covering it over with earth. Where there is not sufficient for this plan, it may be put into trenches between the lines, so that it will be accessible to the feeding-rootlets. The quantity of cattle-manure suitable for 4-year old bushes is 1 *maund* (of 80 lb.) for each 10–20 bushes, decreasing for younger plants.

Diseases and Enemies. Crickets.—These insects attack only young seedlings, whether in the nurseries or in the fields, about 2–3 in. high, cutting through the stem, and carrying away the leafy top to their holes. They seem to be most destructive on low lands, but their ravages cease when the stem of the plant is as thick as a stout pencil. The only remedy is to set boys to work to find their holes, and unearth the insects, paying according to the number brought in.

Ants.—White ants are a much more formidable pest, as they work in myriads, and attack even the largest bushes. Fortunately they have a deadly enemy in the black ant, but other precautions are necessary against them. Between the rains and the setting-in of the cold weather they most frequent the bushes, which latter should be examined for them in the autumn and the spring, and well shaken to effect their dislodgment. The best application to drive them away is petroleum, the refined kinds being more effective but more expensive than the crude. It may be sprinkled after diluting with water, or simply painted in rings around the stems and on the infected spots. Water impregnated with tobacco or tobacco-oil is less permanent in its efficacy.

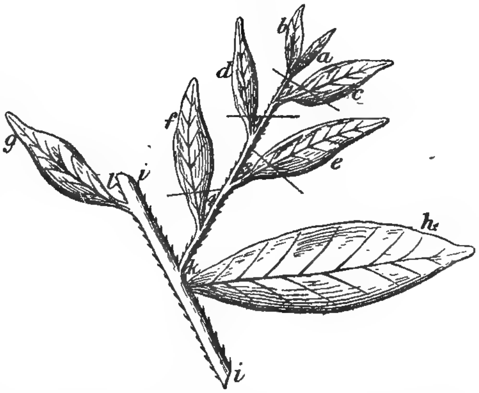
Blight.—This is most detrimental to the yield of a garden, as the young leaves become covered with brown spots, and shrivel up. Money recommends pruning off the diseased branches, and admitting air to the roots by scraping back the soil for 2 ft. round the stem, till the roots are nearly bared.

Flushes and Picking.—A "flush" of the tea-plant is when it throws out new shoots and leaves, the latter constituting the tea of commerce; thus the return from a tea-garden is governed by the number and extent of the flushes per season. These again depend upon the climate, soil, pruning, and cultivation; they may be said generally to range between 25 (in good soil and climate, with high cultivation and plenty of manure), to 18 (where no manure is used, and the cultivation is not high). The average flushing-period is 7–9 months, except for very elevated gardens, when the climate reduces it. Thus, in moderately high situations, it may last from early April to late October, giving 12–15, perhaps 18, flushes; in Upper Assam, Feb. 25 to Nov. 15; Lower Assam, Feb. 20 to Nov. 20; Cachar, Feb. 20 to Nov. 20; Chittagong, Mar. 10 to Dec. 20; Terai below Darjeeling, and W. Dooars, Mar. 1 to Nov. 20. These dates are fixed upon by Money, who considers that 25 flushes should be got within the periods stated. The average intervals between the flushes are approximately 7–14 days, varying with circumstances, and including abnormally long breaks which are sometimes caused by untoward weather.

Fig. 1430 illustrates the way in which the successive flushes occur, and the system of picking recommended by the best authorities. The harder a tea-bush is picked, within certain limits, the greater effort it will make to renew the leaves thus lost, and the greater the yield of leaves to be picked. The ordinary plant at the end of the season measures 3½–4 ft. high and 5 ft. diam., and is then pruned down to 2 ft. high and 3 ft. diam.; thus it remains during hybernation. In the spring, the buds at the bases of all the leaves, and which are the germs of future branches, gradually develop into shoots having 5 or 6 leaves with a closed bud at top. At the bases of these leaves are other buds, which similarly develop in time. The fully developed shoot has 6 leaves, including the bud, marked *a b c d e f*; it has started from a bud *k* at the base of the leaf *h*, and now forms a complete "flush." The leaves *a b*, &c. have also buds 1 2 3 4, which will likewise develop in turn.

Assuming the shoot *k* to be the first on the branch *i*, it forms the basis of future crops on that part of the bush, and must not be removed. But its tendency to throw out new shoots is much increased by nipping off the bud *a*, in such a manner as not to injure the bud at the base of *b*. The lines indicate the points at which the leaves are nipped so as to avoid hurting the buds. The leaves *a b* are covered with a white silky down, and make a white or very pale yellow tea (not infusion), which, mixed with ordinary tea, constitutes "Pekoe tips," and adds much to the value. With the advance of the crop, it is practically impossible, by reason of the great cost for labour, to pick the various kinds separately: but in the first 2 or three flushes, no more than *a* and *b* ought to be picked, and they will then make a small quantity of white Pekoe tips. Later on, the colour becomes orange.

1430.



The value of the leaves depends on their succulence, which is coincident with their youth. The youngest leaf makes the best tea, and the order of merit is :—*a* gives Flowery Pekoe; *b*, Orange Pekoe; *c*, Pekoe; *d*, First Souchong; *e*, Second Souchong; *f*, Congou; *a b c* mixed, Pekoe; *a b c d e* mixed, Pekoe Souchong; if there were a leaf picked below *f* it would make Bohea. The best cultivators do not take any leaf below *e*. The succulent stalk down to the line marked 2 also forms good tea. It would be a great advantage to the product if each leaf could be separately picked and manufactured, so as to modify the treatment according to requirement, but the labour entailed is enormously costly, and the universal practice is to pick and manufacture all indiscriminately, trusting to the final sifting and sorting process (p. 2002) to separate the various kinds with more or less precision.

Money recommends the following plan in picking. If the garden has been pruned as it ought to be, take only *a* for 2 flushes; for 2 more, nip the stalk above 1, taking the upper part of *c*, as shown; from the 5th flush, take off the shoot at the line above 2, and by a separate motion of the fingers take off at *e* at the line. By this plan, when the rains begin, the trees will show a large picking surface, for plenty of buds will have been preserved for new growth. After August, pick lower if desired, as the trees cannot be hurt: for instance, nip the stalk and upper part of *e* together, and separately the upper part of *f*. The principle of picking is to leave intact the bud at the axis of the leaf down to which picking is carried. Some planters pick all through the season at the line above 1, and take *d* and perhaps *e* separately. This plan will make strong teas, but the yield will be small; the plants will also form so much foliage that they will not flush well, and will grow so high that the boy pickers will not reach the top. The principle advocated by Money is to prune severely, so that the plant shall throw out many new shoots; to be sparing with these until the violence done to the tree is in a measure repaired; till September, to pick so hard that the wants of the plant in foliage are never quite attained; and after September, to take all that can be got.

MANUFACTURE.—The aim of the manufacturer should be to produce those qualities which are sought after by the buyer. Brokers judge of tea by the tea itself, the infusion or "liquor," and the spent leaves or "out-turn." The tea should be of uniform greyish-black with a gloss on it; it should be regular in length and twist, and all of one kind. The liquor should have a strong, rasping, pungent flavour; there are many special sub-flavours which cannot be described. The out-turn should be uniformly of the colour of a bright new penny, with greenish rather than black leaves interspersed. Every parcel of tea should be infused and tasted as made, and binned with great care according to its quality. The one difficulty in tea-making is to get Pekoe tips in all Pekoe teas. If the leaves giving tips are separately manufactured,—rolled very little and lightly, not fermented at all, sunned after rolling, and finished in the sun or above the drawers in the *dhole*-house,—they will give perfect white tips; but if mixed with the other leaves, they absorb juice from them in the rolling, and become all black alike. In some instances, it will pay to separate the *a* and *b* leaves by hand; machines invented with that object will be described in due order.

The several processes to which tea is subjected are withering, rolling, fermenting, sunning, and firing or dholing.

Withering.—Withering is effected by a combination of light, heat, and air, best attained by spreading in the sun, when the weather is favourable. Failing this, withering in pans and *dholes* may be resorted to, but always renders the out-turn more or less green. It is better spread on bamboo *mechans* placed in every available sheltered and ventilated space, and on wire-mesh frames suspended so as to draw up under the roofs of the buildings. Ventilated houses of iron and glass have also been built for this purpose. But artificial withering is always inferior to the action of the sun. In dry weather, the leaf as brought in should be spread thinly anywhere that is convenient, and turned once in the night; if not ready for rolling next morning, ½ hour in the sun will generally complete the withering. In unsettled weather, every hour of chance sunshine should be availed of. The tests for properly withered leaf are that it gives no crackling sound on being crushed in the hand, retains the shape to which it is compressed, feels like old rags, and the stalks bend without breaking. Men put in charge of the withering operations should be kept to that alone, and the same rule should be adopted with the other processes.

Rolling.—Some planters advocate circular rolling; some roll the leaf forward, but bring it back without letting it turn; the ordinary forward and backward motion is the simplest and quickest, and that which rollers adopt when given a certain quantity (say 30 lb.) of leaf to roll for a day's work. Rolling in hot pans, formerly extensively practised, is not much done now, and has no advantage. Rolling on coarse mats placed on the floor is a great mistake, as the coarse bamboo mat breaks the leaf, and much of the juice from the leaf, which adds to the strength of the tea, runs through and is lost.

A smooth rigid table 4½ ft. wide, with planks well joined so that no apertures exist for the juice to run through, is best to roll on, especially if covered with a fine *seetul-pattie* mat, nailed down over the edges. A border of wood 1 in. above the surface of the table is screwed on to the edges over the mat, to prevent leaf falling off. The leaf is rolled by a line of men on each side, who pass it up one by one from the bottom of the table to the top. The passage of each handful of roll is regulated by the man at the end, who, when it is rolled enough, forms it into a tightly compressed ball, and puts it on an adjacent stand. The roll is ready to make into ball when it is soft and "mashy," and when it gives out juice freely. This juice is mopped up into the roll, again and again in its passage up the table, and finally into the ball when made up.

Coarse leaves in the roll cannot be twisted, and if left would give much red leaf in the tea. They should be picked out by the 3rd or 4th man from the head of the table, who should not have to roll at all. He spreads the roll and picks out as much as he can between the time of receiving and passing it on, in no case allowing roll to accumulate by him, or it hardens and dries, and gives extra work to bring it into a mashy state again, besides helping to destroy Pekoe ends, and being injurious to the after-fermentation.

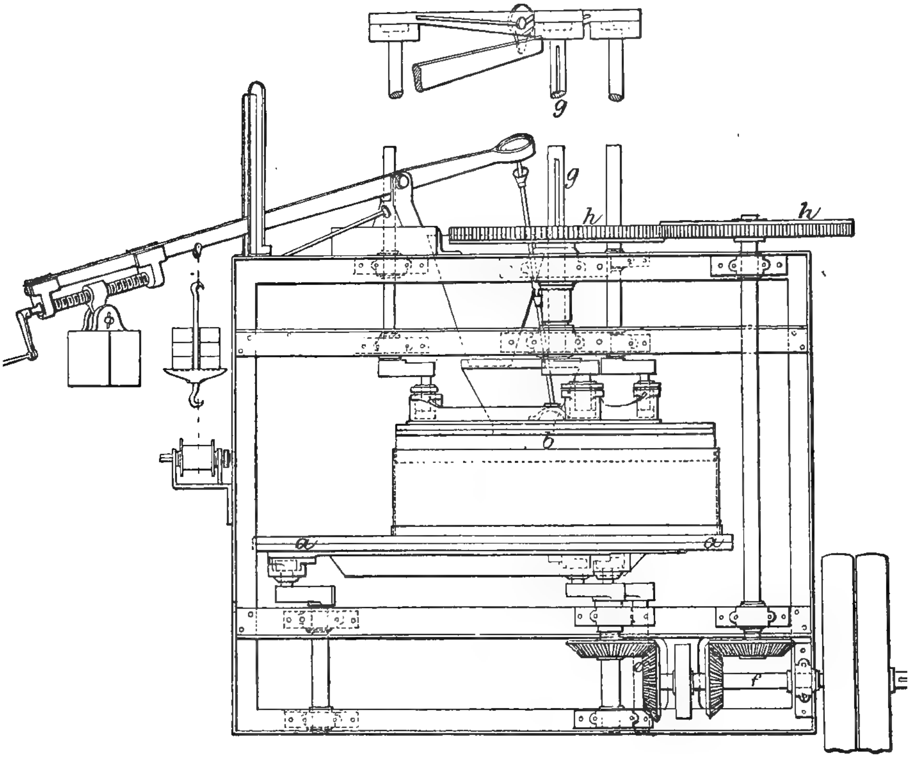
Many apparatus and machines have been invented for rolling tea, mainly with the object of reducing the labour, and increasing the proportion of Pekoe tips.

McMeekin's rolling-table is constructed of battens, so that while rolling, many of the small leaves (Pekoe tips) fall through. This table is well known in Cachar, and used in several gardens, but the objection to it is that the leaf must be rolled lightly, and such leaf cannot make strong tea. Pekoe tips may be in a great measure preserved by rolling all the leaf lightly on a common table, but this plan will not give so many Pekoe tips as McMeekin's table. Planters still feel the want of a machine to separate quickly and cheaply the two said small leaves from the others after they have been picked together. All the other processes can be done cheaply by hand, but this cannot.

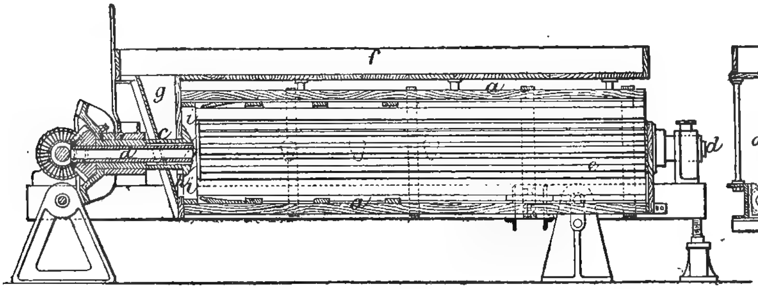
Kinmond's rolling-machine consists of two circular wooden discs, the upper one moving eccentrically on the lower, which is stationary. The adjacent faces of the discs are made rough by steps in the wood, cut in lines diverging from the centre to the circumference, and over these rough faces is nailed coarse canvas. The leaf is placed between the discs and rolled by the motion described, the lower disc being arranged by weights and pulleys, to press against the upper with any force desired. The motive power may be animal, water, wind, or steam. The machine is shown in Fig. 1431. The rolling of the leaves is effected between superposed horizontal plates, *a b*, the opposite faces of which are recessed to a depth of 3–4 in., these recesses being corrugated to aid the rolling and prevent the leaves from slipping. The under plate *a* is mounted upon 3 strong cranks arranged equidistantly in a triangle; the shafts supporting them are carried by exterior plummer-blocks, one having a revolving motion imparted to it by bevel-gearing *e* from a driving-shaft *f*, carried also by exterior plummer-blocks, and provided with fast and loose pulleys. The plate *a* thus receives a horizontal circular traversing motion, but it has no rotating motion around its own axis, neither has it a rising-and-falling motion. The upper plate *b* is similarly suspended from cranks connected by a triangular frame, the shaft *g* having a revolving motion imparted to it by spur- and bevel-gearing *h* from the shaft *f*. The various levers and weights shown are for the purpose of raising the upper plate for the tea to be fed in, and to enable the pressure to be adjusted according to requirement.

Jackson's rolling-machine is an improvement upon Kinmond's, but is declared to be an infringement of the latter. It is shown in Figs. 1432, 1433. *a* is a cylinder composed of teak staves, with an uneven internal surface, mounted so as to be capable of rotation, supported at one end on rollers *b*, on the main frame of the machine, and at the opposite end upon a sleeve *c*, supported in a bearing on the frame. Through the sleeve passes a central shaft *d*, bearing at the opposite end on the main frame

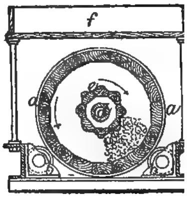
1431.



1432.



1433.



This shaft carries a roller *e*, having an uneven external surface, and of such dimensions that an annular space is left between it and the cylinder *a*. Rotary motion is imparted in opposite directions, as indicated by the arrows, the roller receiving the greater speed. A supply of tea-leaf is introduced into the feeding-trough *f*, whence it passes down a hopper *g*, and through an opening *h*, in the non-rotating end of the cylinder *a*.

No rolling-machine, probably, will supersede entirely the necessity of hand-rolling: a machine is very useful to roll the leaves partly, to break the cells, and bring the leaf into a soft, mashy state, so that very little hand-labour will finish it; but machines do not give the nice final twist which is obtained by the hand. By employing both, very few rolling-men suffice to manufacture a large quantity of leaf.

Nelson's rolling-machine does not profess to do more than prepare the green leaf for rolling. The leaf is placed in bags, and compressed under rollers attached to a box weighted with stones. The inventor states that it will prepare 80 lb. of green leaf in 15 minutes, and that one man can then finish as much prepared leaf in 3 minutes as would otherwise occupy him 12 minutes. The machine is inferior to Kinmond's in arrangement, and ought to be very cheap, as it is simply a mangle.

Fermenting.—The balls accumulated by the rolling-men are allowed to stand until fermented, which is, perhaps, the most important point in the whole manufacture. Some planters collect the roll in a basket, and let it ferment there instead of in balls. But when a quantity is put into a basket and allowed to ferment a certain time, the first part is more fermented than the last; while balls can be taken in the order in which they were laid on the table, and thus each will receive the same amount of fermentation. Further, the twist is better preserved by the balls, and a large quantity in a basket is apt to ferment too much in the centre. It is impossible to describe with useful accuracy when the balls are sufficiently fermented. The outside is no criterion, as it varies much, according to the degree of withering. The more the leaf is withered, the thicker in consistency and the smaller in quantity is the juice that exudes, as also the yellower in colour; further, the darker is the outside of the balls. Bright rusty-red is the colour of moderately-withered leaf; very dark greenish-red when much withered. A good rule is that half the twisted leaves inside shall be rusty-red, half green; but practice alone can guide. The process is quicker in warm than cool weather, but requires no fixed time. It should be stopped in each ball just at the right moment by breaking up the ball, and spreading it out very thin; at the same time any remaining coarse leaves are picked out.

Sunning.—The fermented roll is immediately spread very thin on *dhallas* or mats in the sun. When become blackish in colour, it is collected and re-spread, so that the whole shall be equally affected. In bright sunshine, an hour or less suffices; it is then placed at once in the *dholes*, previously got ready to receive it. In wet weather, directly the balls are broken up, and the coarse leaf is picked out, the tea is sent to the *dholes*; but the best tea is made in fine weather.

Firing or Dholing.—The least delay between breaking up the balls and beginning to drive off the moisture is injurious. In wet weather, unless there are many *dholes*, time will not permit each roll to be finished. The only plan then is to half-fire them, to avoid injury by delay; but in any other case, the roll should not be removed from the drawer until it has become tea. The roll in each drawer is shaken up and respread 2 or 3 times during the firing. The rolls remain in the drawers under the influence of the heat of the burning charcoal till it is quite dry and crisp, and thoroughly brittle.

By the old plan of firing, a single wicker sieve was inserted in a bamboo frame called a *dhole*, placed over a charcoal fire in a hole in the ground. Several inventors have improved upon this crude and wasteful method. McMeekin's chest of firing-drawers, now generally used, consists of a system of drawers or trays fitted in a frame one above another, the bottom of each tray being made of fine iron wire, so that the heat of the charcoal, in the masonry receptacle over which it is placed, ascends through all the drawers, and "fires" or dries a large quantity of "roll" at the same time. The economy of fuel is great, but Money thinks that with 4 or 5 superimposed drawers, the steam ascending from the lower ones must more or less injure the roll above; he confines himself to two, and in the top tray leaves a small circular space by which the steam from the lower drawer can escape. The escaping heat is partially utilized by placing *dhallas* in tiers above, with roll in them, supported by iron rods let into the wall; they are useful for partly drying roll, and for withering leaf when there is no sun.

Some planters have proposed to do away with charcoal under McMeekin's drawers, supplying its place by hot air. It was long supposed that the fumes of charcoal were absolutely necessary to make good tea. Col. Money has disproved this by making as good or better tea without charcoal, and drying chambers using hot air generated in outside furnaces are coming into favour. The advantages are:—(1) The economy of $\frac{6}{7}$ of the fuel used; (2) cleanliness and absence of charcoal-dust; (3) absence of the objectionable carbonic acid fumes of charcoal; (4) immunity from fire; (5) greater speed in the firing process, and saving of all the labour employed to make charcoal; (6) reduced temperature in the tea-houses.

Green Tea.—For green tea, the leaf is brought in twice daily: that coming in at 1 P.M. is partly made the same day; that brought in at evening is spread 6 in. thick till next morning. If either arrives wet, it must be dried, the former before going into the pans, the latter before being spread. The dry leaf is put into thick pans, 2 ft. 9 in. diam. and 11 in. deep, set sloping over fireplaces, and numbering 4 or 5 for every *maund* (80 lb.) of tea to be made per diem. The pans are heated to about 71° (160° F.), and the leaf is stirred for about 7 minutes with flat sticks, till it becomes moist and sticky. It is next rolled on a table till it gets a little twisted (say 2 or 3 minutes), and is laid out 2 in. thick on *dhallas* in the sun for 3 hours, being rolled three times in that period, for not more than 3 minutes each time, when it has become blackish on the surface; it is then spread out as before. After 3 rollings, it should have a good twist. It is replaced in the pans at the same heat, and worked with the stick till it is too hot to hold (say 2–3 minutes). Next it is stuffed as tightly as possible into bags 2 ft. long and 1 ft. broad, made of No. 3 canvas; the mouths are tied up, and the bags are beaten heavily to consolidate the contents, and thus left for the night. In the morning, the tea is turned out, and worked with the sticks in the pans at a temperature gradually falling from 71° (160° F.) to 49° (120° F.): the green colour is thereby produced. The leaves of the Chinese plant make the best green tea, while hybrids are best for black.

Sifting and Sorting.—These operations constitute a very important item in the manufacture, as they may make a difference of 2–3 annas a lb. in the selling-price of the tea. Tea-sieves are round, and either of brass wire with wooden sides 3½ in. high, or of cane with bamboo sides 1¼ in. high. The latter are Chinese, and superior in every way to the former. Both are numbered according to the orifices in 1 linear in., the brass numeration including the diam. of the wire, and thus giving a slightly less aperture than the corresponding number in cane sieves. Tea should be sifted daily, taking that made on the previous day, and be binned in that state. For daily sifting in an ordinary garden, the sieves (Chinese) required will be: 4 of No. 4, 6 of No. 6, 6 of No. 7, 9 of No. 9, 9 of No. 10, 6 of No. 12, 4 of No. 16. Red leaf is carefully picked out before commencing to sift. No rules can be laid down for sifting and sorting; much practice is required to make an efficient sifter, and no two batches of tea will demand precisely the same treatment. Hence the general failure of sifting-machines for this purpose, since they cannot be worked economically and at the same time adjusted to suit all needs; fanning-machines, however, may be used to separate dust and open leaves.

The classification of black tea is according to the size, make, and colour of the leaf, the ordinary descriptions being Flowery Pekoe, Orange Pekoe, Pekoe, Pekoe Souchong, Souchong, Congou, Bohea; and of broken kinds, Broken Pekoe, Pekoe Dust, Broken Mixed Tea, Broken Souchong, Broken Leaf, Fannings, and Dust.

Flowery Pekoe generally preserves a uniform greenish-grey or silver-grey tint. Its liquor is very strong, in flavour approaching green teas, but infinitely superior, having their strength and astringency without their bitterness; it is pale, and the infused leaf is of a uniform green hue. When too much heat has been employed, dark leaves are intermixed, and the prevailing green is sprinkled with leaves of a salmon-brown tinge, which is the proper colour for the out-turn of any other ordinary black tea. A common mistake is to call ordinary Pekoe containing an extra amount of Pekoe ends, Flowery Pekoe. When strong and of Flowery Pekoe flavour, it is called a Pekoe of Flowery Pekoe kind. In England, Flowery Pekoe is worth about 4*s.* 6*d.*–6*s.* 6*d.* a lb.

When the Pekoe ends are yellowish or orange, and the leaf is very small and even, the tea is called Orange Pekoe. In flavour, it is much the same as ordinary Pekoe, and many growers send away the two varieties in the finished state mixed together. Its value is 2–4*d.* a lb. more than Pekoe.

Ordinary Pekoe is of blackish or greyish-black aspect, dotted over with greyish or yellowish leaves possessing the downy appearance which gives the name to Pekoe. In general, the whole leaf is not covered with down, but only a part of it which has been developed late. These are called "Pekoe ends" when very small. Pekoe is generally of good to fine flavour, and very strong, and its liquor is dark. Its value is 2*s.* 9*d.*–3*s.* 8*d.* a lb.

The term Pekoe Souchong is generally applied to a Pekoe that is deficient in Pekoe ends, or to a bold Souchong leaf with a few ends mixed. It is often applied to an unassorted tea, including perhaps Souchong, Congou, a few Pekoe ends, and some broken leafs. Prices average 2*s.* 3*d.*–2*s.* 10*d.* a lb.

Broken Pekoe is Pekoe which has been broken in manipulation or otherwise. It possesses the strength and fine flavour of a full leaf of Pekoe, being therefore only inferior to it in point of leaf. In value, it is very little inferior to Pekoe, sometimes even superior, as the tender Pekoe ends are frequently broken off in large quantity, adding to the value of the broken tea, while deteriorating the Pekoe. Ordinary prices are 2*s.* 6*d.*–3*s.* 4*d.* a lb.

Pekoe Dust is broken so small as to resemble dust. It is of great strength, though often not pure in flavour, as frequently any dust or sweepings from other tea is mixed with it to make the lot larger. The price may range from 1*s.* 6*d.* to 2*s.* 8*d.* a lb.

Souchong may be taken as the medium quality, and, when experience and skilled labour are employed in the manufacture, as the bulk of the produce of an estate. The qualifications are an even, straight, or slightly curved leaf, ½–1½ in. long. It has not the deep strength of Pekoe, but is generally of good flavour and fair strength. Prices are 1*s.* 10*d.*–2*s.* 8*d.* a lb.

Congou may be either a leaf of Souchong kind, but too large to come under that class, or a smallish-sized leaf, too unevenly made, or too much curled. The flavour is much the same as that of Souchong, but the tea has less strength. Some of the lower and large-leaf kinds may be only worth 1*s.* 3*d.*–1*s.* 6*d.*, whereas finer qualities sell at 2*s.*–2*s.* 3*d.* a lb.

Bohea may be either of too large a leaf to be called Congou, or, as is generally the case, may consist principally of old leaf, which, on being fired, does not attain the greyish-black colour desirable in all black kinds except Flowery Pekoe, but remains of a brownish or pale-yellowish hue. It has scarcely any strength, is generally of coarse flavour, and is never of much value unless of Namuna kind. Prices are 3*d.*–1*s.* 2*d.* a lb.

Broken Mixed Tea is a mixture of the various kinds broken, and may include some of the lower classes, or approach Broken Pekoe in character and value; but it is usually worth 1*s.* 8*d.*–2*s.* 6*d.* a lb., and of a blackish aspect, containing a few Pekoe ends.

Broken Souchong is a tea, which, though broken, has some approach to a full leaf of the even Souchong character. Value, 1*s.* 6*d.*–2*s.* 2*d.* a lb.

Broken Leaf is a term of great comprehensiveness, but generally signifies a tea worth 8*d.*–1*s.* 1*d.* a lb., of brownish, brownish-black, or blackish colour. Its strength is seldom great; its flavour may be fair or good, but in the lower qualities is generally poor, thin, or coarse.

Fannings is similar in colour and class to broken leaf; in value it is also much the same, perhaps on the average a little lower.

Dust is very small broken tea. It is often very coarse or "earthy" in flavour, owing perhaps to sweepings and dust having become mixed with it. Its value is 6*d.*–1*s.* 6*d.* In any worth more than these quotations, a few Pekoe ends or tips will be found, bringing it under the name of Pekoe Dust.

Another class of tea possessing very great strength and very fine flavour is known as Namuna. The leaf may have perhaps the ordinary greyish-black aspect, with generally a greenish tinge. In the pot, it produces a very pale liquor, but its quality is stronger by far than ordinary Pekoe; in flavour, it is about half way between Flowery Pekoe and a green tea, quite distinct from Flowery Pekoe, possessing somewhat of the rasping bitterness of the green-tea class with the flavour a little refined. The out-turn is generally green, sometimes with brownish leaves mixed. Any black tea may be of this class, from Pekoe to the lowest dust, and all, if the flavour be distinct and pure, may have their value enhanced 4–10*d.* a lb.

Similar in all respects but one, is Oolong. The wanting quality is strength. Sometimes the flavour is a little different. It is generally composed of greyish-black leaves with a few green ones intermixed; it always has a pale liquor, generally a greenish infused leaf; but its flavour is frequently burnt out, though its weakness and green appearance are often caused by deficient firing. Teas of this kind on the average sell below the ordinary-flavoured teas of the same class of leaf.

In teas of ordinary flavour, the following rules hold good:—The darker the liquor, the stronger the tea; and the nearer the infused leaf approaches a uniform salmon-brown, the purer the flavour. Whenever black leaves are mixed with the out-turn, the tea has been over-fired, and the strength is either burnt out of it, or a burnt or smoky flavour is given. An altogether black or dirty-brown out-turn is certain to give pale liquor of little or no strength, and no flavour unless it be sour. This sourness is of various grades,—slightly sourish, sourish, and sour, depreciating the value 3*d.*–1*s.* 6*d.* a lb. The flavour is hardly capable of description. The least tendency to it condemns the parcel at once. The cause assigned for it is that the leaf after being picked is allowed to remain too long in the raw state before being fired, undergoing fermentation.

Burntness may either destroy the strength and flavour altogether, or, without destroying the strength, add an unpleasant burnt flavour, when the tea is called "smoky" or "smoky burnt," and deteriorated in value 2*d.*–1*s.* a lb. Symptoms of burntness are a dead-black leaf, having a burnt smell which often entirely neutralizes the natural aroma. The terms "fresh burnt," "brisk burnt," "malty burnt," are not condemnatory, and the word burnt, as used here, would be better expressed by fired. "Malty" means of full rich flavour. "Full," applied to a liquor, does not signify strength or flavour, but is opposed to thinness. A green tea may be strong or of good flavour, but its liquor is never full. Fulness is generally characterised by a dark liquor, and is akin to "body" in a wine. "Chaffy" is generally used for Bohea and other brown-leaf classes. A light, open, brown leaf would be called chaffy. The lower classes, especially dusts, are often described as "earthy" in flavour, perhaps caused by the admixture of real dirt.

When a tea is spoken of as "well made," "fairly made," &c., the manipulation is referred to. There are "straight" and "curled," or, as the latter is generally expressed when applied to large leaf, "twisted" leaves. It may be "flattish made," indicating that though the leaf is not open, it wears a flattish aspect, or it may be open, which betrays a want of sufficient or skilful manipulation.

A "wiry" leaf is small, perfectly rolled, and very thin (in diameter) generally rather curled, so as to resemble small pieces of bent wire. Only the finer teas can have a wiry leaf, principally the Orange Pekoes and Pekoes. Sometimes a fine Souchong may be thus described.

Of green teas, Gunpowder is the most valuable description, its price ranging from 2*s.* 8*d.* to 3*s.* 8*d.* a lb. Instead of possessing the long and thin finished leaf, which is the desideratum of black teas, it is rolled into little balls ⅛–¼ in. diam. Sometimes it has some long leaf mixed.

Tea of the shape of Gunpowder, but larger, is called Imperial. Prices are 10*d.*–2*s.* 6*d.* a lb.

Hyson may be taken as the parallel of Souchong in black-leaf descriptions. There is often much young Pekoe leaf in it, but all chance of discovering it in the finished leaf is precluded by the change in colour. Hysons sell at 1*s.* 2*d.*–3*s.* 6*d.* a lb.

Young Hyson is smaller than Hyson, occasionally slightly broken. It fetches 7*d.*–2*s.* 6*d.* a lb.

Hyson skin consists of bold broken Hyson and young Hyson. A small broken green tea is seldom sent on the home market. The reason is obvious: when Hyson skin only fetches 7*d.*–1*s.*, anything approaching dust would give very little chance of profit. It would be well if all planters would take a lesson from the Chinese, and not send home their very low teas, black or green, as they are very difficult of sale in London, and in many cases cannot pay the cost of packing and shipping. The Chinese make much of their broken teas into brick tea, and send it into Central Asia, where it meets with a ready sale. In the N.-W. Provinces, the natives are beginning to consume largely, and will pay 8 annas to 1 rupee for tea that would not fetch more than 1*s.*–1*s.* 6*d.* in England. Whether the natives of India, as a whole, do or do not take to drinking tea, will have a material effect on the future prospects of the industry. The manufacture of green teas is probably less remunerative than that of blacks, and there is far less demand for them in England, though considerable in America.

Caper is made in large quantity in China. It forms a link between the black and green descriptions. The colour of the leaf is a very dark green; in form, it is similar to a Gunpowder, Imperial, or round-leaf Congou; the liquor is pale, and the out-turn green; flavour, perhaps nearer to that of green than black tea.

Packing.—The best tea-boxes are of teak, made at Rangoon. The wood is sawn by machinery into pieces which will make each chest measure inside 23 × 18 × 18½ in.; the contents are 7659 cub. in., sufficing for above 1 *maund* (80 lb.) of fine, and under 1 *maund* of coarse tea. Each box is composed of fourteen pieces, nailed together with "French pins," 1¾ in. long. It is extremely important that the tare of all the boxes shall not vary more than ½ lb., or the whole will be turned out and reweighed in London. All the boxes are lined inside with a thin leaden shell.

Tea may be packed only on fine hot days. It is first "bulked," i. e. turned out on a cloth and mixed most intimately. It is also finally dried to remove the moisture imbibed during storage, even though kept in zinc-lined bins. Sun-drying is far best. The tea is put into the box while hot, first taking enough to ¼ fill the box. This is rocked till it is thoroughly settled, and then trodden down by a man standing on a piece of carpet; this is repeated with decreasing instalments, dispensing with the rocking for the last 2 or 3 additions. When full, a sheet of "silver" paper is laid on the tea to catch drops caused while soldering the top, which, with the nailing on the cover, is the final operation. To take the tare of the boxes, they are weighed with the leaden lining and leaden top; when filled and soldered, but before putting on the wooden top, they are again weighed for the gross. The tares must be equalized by adding nails, solder, or hoop-iron bands. The boxes are finally marked.

Cost of a Tea Garden.—Col. Money gives the following approximate estimate of the cost to establish a 300-acre tea-garden:—

1*st year.*	*Rs.*	
700 acres of land, at Rs. 8	5,600	(560*l.*)
40 *maunds* of seed, at Rs. 70	2,800	(280*l.*)
Nurseries for vacancies, and labour of transplanting	200	(20*l.*)
First temporary buildings	1,000	(100*l.*)
Cost of planting 100 acres, at Rs. 80	8,000	(800*l.*)
Cultivating 100 acres 1st year, at Rs. 50	5,000	(500*l.*)
	22,600	(2,260*l.*)

2*nd year.*		
60 *maunds* of seed, at Rs. 70	4,200	(420*l.*)
Nurseries, and labour of transplanting	300	(30*l.*)
Repairs and new buildings	500	(50*l.*)
Cost of planting 2nd 100 acres, at Rs. 70	7,000	(700*l.*)
Cultivating 1st 100 acres, at Rs. 60, and 2nd 100 acres, at Rs. 50	11,000	(1,100*l.*)
	23,000	(2,300*l.*)

TEA.

3rd year.

	Rs.	
70 *maunds* of seed, at Rs. 70	4,900	(490*l.*)
Nurseries, and labour of transplanting	400	(40*l.*)
Buildings for manufacture (temporary), and repairs	3,000	(300*l.*)
Cost of planting 3rd 100 acres, at Rs. 60	6,000	(600*l.*)
	14,300	(1,430*l.*)
Cultivating 1st 100 acres, at Rs. 70, 2nd at Rs. 60, and 3rd at Rs. 50	18,000	(1,800*l.*)
Interest on 1st year's outlay for 2½ years, 2nd year's for 1½ year, and 3rd year's for ½ year, at Rs. 5 per cent. per annum	5,357	(535*l.*)
Total cost of making 300-acre garden	83,257	(8,325*l.*)

4th year.

20 *maunds* of seed, at Rs. 70	1,400	(140*l.*)
Nurseries, and labour of transplanting	500	(50*l.*)
Repairs to buildings	500	(50*l.*)
Cultivating 1st 100 acres, at Rs. 80, 2nd at Rs. 70, and 3rd at Rs. 60	21,000	(2,100*l.*)
	23,400	(2,340*l.*)

5th year.

10 *maunds* of seed, at Rs. 70	700	(70*l.*)
Nurseries, and labour of transplanting	500	(50*l.*)
Repairs to buildings	500	(50*l.*)
Cultivating 1st 100 acres, at Rs. 90, 2nd at Rs. 80, and 3rd at Rs. 70	24,000	(2,400*l.*)
	25,700	(2,570*l.*)

6th year.

Nurseries, and labour of transplanting	500	(50*l.*)
Repairs to buildings	500	(50*l.*)
Cultivating 1st 100 acres, at Rs. 100, 2nd at Rs. 90, and 3rd at Rs. 80	27,000	(2,700*l.*)
	28,000	(2,800*l.*)

7th year.

Nurseries, and labour of transplanting	500	(50*l.*)
Building permanent factory and store, and repairs to buildings	12,500	(1,250*l.*)
Cultivating 1st 100 acres, at Rs. 100, 2nd at Rs. 100, and 3rd at Rs. 90	29,000	(2,900*l.*)
	42,000	(4,200*l.*)

8th year.

Nurseries, and labour of transplanting	500	(50*l.*)
New permanent houses for manager and assistant, and repairs to buildings	8,500	(850*l.*)
Cultivating 1st, 2nd, and 3rd 100 acres, at Rs. 100	30,000	(3,000*l.*)
	39,000	(3,900*l.*)

9th and all succeeding years.

Nurseries, at Rs. 500 Repairs to buildings, at Rs. 500	1,000	(100*l.*)
Cultivating 300 acres, at Rs. 100	30,000	(3,000*l.*)
	31,000	(3,100*l.*)

Cost of Manufacture.—The cost of manufacture, sorting, packing, freight, and brokerage, per *maund* (80 lb.) of tea is given by Money as follows:—

	R.	A.	P.	s.	d.
Manufacture.					
1 head man with the pickers	0	4	0	0	6
320 lb. green leaf picked, at 1 pie	5	0	0	10	0
1 man withering leaf, at 4 annas	0	4	0	0	6
¼ share head man in rolling-house	0	2	0	0	3
10⅔ men rolling, at 30 lb. leaf per man, and 4 annas per man	2	10	8	5	4
¼ boy clearing out ashes of *dhole*-house, at 2 annas	0	0	6	0	0¾
¼ share head man in *dhole*-house	0	2	0	0	3
1 man firing *dhole* work	0	4	0	0	6
¾ *maund* charcoal for *dhole* work, at 8 annas	0	6	0	0	9
Lights for night work, viz. turning green leaf and *dholing*, say	0	4	0	0	6
Wear and tear of *dhallas*, baskets, picking-baskets, fuel for artificial withering, &c.	0	1	10	0	2¾
	9	7	0	18	10½
Sifting and Sorting.					
1½ boys to pick out red leaf, at 2 annas	0	3	0	0	4½
1 sifting man, at 4 annas	0	4	0	0	6
Wear and tear of sieves	0	0	3	0	0½
	0	7	3	0	11
Packing.					
1 box	1	13	0	3	7½
4 sheets lead, viz. 2 large and 2 small	1	6	6	2	9¾
Labour of lining box with lead, solder, closing lead, closing wooden box, stamping, and nails	0	0	9	0	1
Labour of drying previous to packing, in sun or over *dholes*, including charcoal if latter are used	0	0	9	0	1
Labour of filling box, shaking, and pressing the tea (2 men)	0	0	6	0	0¾
	3	5	6	6	8
Transport.					
Freight to Calcutta for 1 *maund* tea	1	12	0	3	6
Brokerage.					
Landing, lotting, and advertising, per chest	0	14	0	1	9
Brokerage at 1 per cent. on the amount sale, say Rs. 70 per *maund*	0	11	3	1	5
	1	9	3	3	2

Total for 1 *maund* (80 lb.) of tea 16R. 9A. 0P. (1*l.* 13*s.* 1½*d.*)

If more than 2 *maunds* are made per diem, some of the items will be a little less. In large quantity, about 12–13 Rs. (24–26*s.*) would cover everything.

Brick-tea.—The article known as brick-tea is of three kinds. The first, or largest kind, is a cake of coarse green tea, which weighs, when thoroughly dried, about 3½ lb., and is about 1 ft. long by 7 in. wide. These cakes are made in a wooden mould while wet, compressed by a lever-press, and afterward dried, all by hand-labour. When dried, each cake is wrapped in paper and packed in strong baskets, each containing 36 cakes. The cost of this tea per basket is about 28*s.*, and the annual exportation from Kiukiang amounts to 15,000–20,000 baskets. The tea is sent from Kiukiang to Tientsin, whence it goes overland through Mongolia for consumption among the inhabitants of W. and N.-W. Siberia, in the province of Kazan, on the Volga, and by the Kirghis and other tribes. A cake of tea of the same form, but of a much commoner quality, costing about 22*s.*, made by the Chinese at Yang-lout'ung, in Hupeh, is largely consumed in Mongolia.

The second kind of brick-tea is of a finer quality, each cake weighing 1½ lb., and being 8¼ in. long by 5¼ in. wide. It is packed in baskets, each containing 80–90, and costs about 34*s.* per basket. This kind is consumed in W. and S.-W. Siberia, at Kazan, and on the Amoor.

The third kind of brick-tea is made of black-tea dust, each cake weighing 2¼ lb., and being 8½ in. long by 6 in. wide. It is packed in baskets containing 64 cakes each, and costs about 33*s.* per basket. It is consumed throughout Siberia and in E. European Russia by the peasantry. It is made into cakes at Foochow, Kiukiang, and Hankow. The yearly exportation from the three places is about 100,000 baskets. The brick-tea trade of Hankow is rapidly increasing, and the demand becoming greater than the supply. The employment of steam machinery for pressing the bricks has proved a great success, the steam-pressed brick being much better finished than by hand, and more compact and firm, standing transit better, and arriving at its destination little the worse for its journey. With the old method, the bricks, from insufficient pressing power, were liable to chip and crumble at the edges, while great stress is laid on the perfect appearance of the brick by the Siberians. Both methods of manufacturing brick-tea have a serious drawback in the damping of the dust by steam, which robs it of all its fragrance. To remedy this defect, hydraulic presses have been introduced, which turn out small corrugated cakes, weighing ¼ lb. each, retaining the original aroma in all its freshness. It is yet uncertain whether the compressed tea will prove a success, but samples sent to Siberia have been favourably reported on; and though probably the brick will keep its position among the masses, the compressed tea will become popular with the better classes, and if really fine dust be employed in its manufacture, it may, from its portability and cheapness, generally take the place of the leaf-tea at present annually sent overland from Shansi.

The following is the method of producing the brick-tea. There are at present 6 manufactories in Hankow, 3 of which use boilers either for steaming the tea, or both for that and furnishing power for pressing. The dust from which brick-tea is made comes principally from Ningchow in Kiangsi, and Tsung-yang and Yang-lout'ung, in Hupeh, and varies both in fineness and cost according as it belongs to the first, second, or third crop. The first operation is to sift the dust and reject all the sand and rubbish contained in it, usually amounting to about 5 per cent. It is then placed in a winnowing-machine, having 3 different-sized sieves, with troughs corresponding, and passed into baskets. The residue which is too coarse to pass any of the sieves is taken out and trodden until it is reduced to the proper consistency, when it is placed in iron pans over a charcoal fire until it is sufficiently brittle, and is again taken to be winnowed; this operation is repeated until all has been sifted to the requisite degree of fineness. Three sizes are produced, the coarser ones being employed to constitute the brick, while the finest dust is only used as a facing. The dust having been properly sifted, the next step is to prepare it for pressing, by exposing it to the action of steam for 3 minutes; it is this steaming that robs brick-tea of its scent and flavour, and for which a remedy is eagerly sought.

The old-fashioned apparatus of native design consists of 6 iron boilers heated by charcoal, and having spaces above fitted with rattan covers. When the dust is to be steamed, it is spread out on a sheet of cotton cloth, placed over the boiler, and covered up; but with the improved European apparatus, the dust is simply put into iron boxes, and the steam is passed through them. After having been sufficiently steamed to make it adhesive, the dust is put into a strong wooden mould (on the movable cover of which, the trade-mark of the hong or firm is engraved, so as to leave the corresponding impression on the brick), and firmly wedged down. It is then pressed, and placed on one side for 2–3 hours to cool. Each brick should weigh 1 *catty* (1⅓ lb.), and all those that do not come up to the proper standard of weight, or are defective in any way, are rejected and remade. For this purpose, they are taken to an edge-runner mill, constructed of two heavy circular stones, moved by a horizontal wooden bar, and working in a channel, where the condemned bricks are thrown and crushed by the wheels. Having again become dust, the operation already described is repeated. The hand-press turns out 60 baskets a day, with 25 per cent. of failure bricks; while the steam-press produces 80 baskets a day, with only 5 per cent. of bad work, and the saving, by the employment of the improved machinery, amounts to 1 *tael* (5*s.*) a basket, or, according to the above-stated out-turn, 80 *taels* (about 20*l.*) a day. The bricks found to be correct in weight and free from defects are stored in the drying-room for a week, when they are carefully wrapped separately in paper, and packed in bamboo baskets containing 64 each. Green brick-tea is made in the same manner, but of leaf, not dust, and the bricks are larger.

It is expected that in a short time the whole trade will be transferred to Hankow. In addition to brick-tea proper, there is another kind of tea, called "medicine tea," which is composed of coarse leaf and stalks, mixed with various kinds of medicinal herbs, and packed in bundles weighing 64 *catties* (of 1⅓ lb.). It is valued at 5 *taels* (25*s.*) per *picul* (133⅓ lb.), and in the event of the cost of transhipment to Central Asia viâ Tientsin, instead of as hitherto from Shansi, proving sufficiently low, it is expected that the trade will receive increased attention. Owing to the immense quantities of brick-tea now arriving at Tientsin for transport overland, it is anticipated that the sea and river route viâ Tientsin and the Amoor will soon be substituted for camels. Kiukiang exported 681,333 lb. of brick-tea in one year.

Production and Commerce.—America.—Tea culture was attempted more than 10 years ago in California, and great expectations were expressed with regard to the Sacramento Valley in particular; but no material success seems to have been gained. More recently, renewed attention has been given to the subject in the S. States, and a plantation has been selected near Charleston for experiment, it being supposed that the climate of S. Carolina, near the coast, is very suitable for tea-growing. The main difficulty is want of cheap labour. America forms the chief market for green teas.

Azores.—It was officially announced in 1879 that the tea plant was growing luxuriantly in St. Michael's, and that Chinese were engaged to teach the methods of preparing the leaf. Satisfactory results were obtained from experiments.

Ceylon.—Tea cultivation is progressing rapidly in several districts and at various elevations up to 4500–6000 and even 7000 ft., and a very fine-flavoured tea can be produced. In 1880, about 100,000 lb. were exported; and in 1881, up to the close of the season (30th Sept.), 278,590 lb. Ceylon teas distinguished themselves at the Melbourne Exhibition.

China.—The districts specially devoted to tea-farming in China lie between 23° and 25° N. lat., and 115° and 122° E. long., comprising portions of the provinces of Canton, Chekiang, Fokien, Honan, Hupeh, Kiangsi, and Kiangsu. Now that Western science and skill have been introduced with such marked effect in the preparation of tea in India, there is no valid reason for reproducing an account of the complicated Chinese methods; in fact, though China remains by far the largest producer of tea, that country will henceforward be of far less interest to the English tea-grower and merchant than our own tropical possessions. The exports to foreign countries from Amoy in 1879 were:—

Destination.	Congou.	Oolong.	Souchong.	Dust.	Mixed.	Black.	Total.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Great Britain ..	62,149	570,855	..	..	..	..	633,004
United States ..	604,636	15,456,723	40	16,122	116,921	254,863	16,449,305
Straits	112,289	280,620	5,328	..	..	..	398,237
Java	302,608	318,239	3,838	..	..	..	624,685
Siam	63,571	37,452	412	..	..	..	101,435
Manila	17,945	3,657	378	..	240	..	22,220
Saigon	128,177	88,584	300	..	..	..	217,061
Hong Kong ..	374,240	3,048,993	43	..	..	..	3,423,276
Total ..	1,665,615	19,805,123	10,339	16,122	117,161	254,863	21,869,223

The exports from Canton (in *piculs* of 133⅓ lb.) in 1879 were as follows. (The bulk of the black tea sent from these waters is called scented tea, and the flower used for scenting (*Jasminum Sambac*), goes by the name of *mok-lei;* the gardens where this plant is cultivated are principally in the Honam and Fatee suburbs of Canton. The essential oil of this species is considered inferior to that named on p. 1422.)

Destination.	BLACK.								GREEN.						
	Congou.	Souchong.	Orange Pekoe.	Scented Caper.	Oolong.	Pouchong.	Pekoe.	Total.	Young Hyson.	Hyson.	Imperial.	Gun-powder.	Total.	Black.	Green.
														lb.	lb.
Great Britain ..	13	..	193	1,466	..	..	..	1,672	..	..	..	..	..	222,993	
Hong Kong	15,849	4,831	19,244	67,019	436	2,654	42	110,075	40	253	559	2,880	3,733	14,676,691	497,792
Sandwich Islands	469	..	..	..	..	48	1	518	..	..	..	..	..	69,057	
Tientsin	..	..	..	..	..	..	..	..	..	..	..	..	..	13	
Chefoo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
Shanghae	46	..	1	..	..	..	..	48	..	97	..	47	144	6,359	19,224
Total	16,377	4,831	19,438	68,485	436	2,702	43	112,313	40	350	559	2,927	3,877	14,975,113	517,019

Foochow, in 1879, exported 81,421,600 lb. to Europe, the Colonies, and America, besides 4,372,800 lb. to Chinese ports for reshipment. The exports were distributed as follows:—Great Britain, 61,505,584 lb.; Australia, 13,042,800 lb.; Hong Kong, 3,759,883 lb.; S. Africa, 1,023,867 lb.; United States, 888,800 lb.; New Zealand, 857,200 lb.; Continental Europe, 204,400 lb.; Russia, 139,066 lb.

Congous figure for 73,138,133 lb., chiefly of the common and medium kinds; and Souchongs for 4,693,867 lb., mostly to Great Britain, S. Africa, Continental Europe, America, and Hong Kong. The consumption of fine scented teas, such as Orange Pekoe and Caper, as well as of Oolongs, is greatly interfered with by Indian tea. Foochow has now become of but little consideration in the production of Oolongs, being cut out by the increasing quantity prepared in Formosa and Japan under the superintendence of foreigners, and through the inordinate quantity of tea-dust that was mixed with it, the bulk of the Foochow leaf is now manufactured into Saryum Congou. Attempts have been made to introduce Indian tea-seed, to improve the quality of tea from this port, but so far they have not met with any encouragement. A considerable trade has sprung up between this port and Russia, either direct to Odessa, generally in British bottoms, or viâ Tientsin overland to Kiachta. Three Russian firms are connected with this trade, and have establishments here and in the neighbourhood of Yenping, principally for the manufacture of brick-tea by steam process. It is surprising that British firms have not, in the same manner, taken to making brick-tea for exportation. Being portable, and taking up little room, it would be suitable for army supplies. The Russian firms export, besides brick-tea, the best qualities of Pehlings, Panyangs, and Paklums, and can afford to give a higher price than buyers for the English market.

Hankow in 1879 exported 511,213 *piculs* (of 133⅓ lb.) of black tea and dust, value 3,810,197*l.*; 144,756 *piculs* of black brick-tea, 145,957*l.*; and 25,651 *piculs* of green brick-tea, 35,619*l.*

Ichang exported of black tea only 36 *piculs* in 1878, and 91 in 1879. The Chi tea, so called from the place where it is grown,—Lo-tien-chi, near Ichang,—is considered very good, but is scarcely known to foreigners. Hao-fêng, Shi-nanfoo, and Patung are also tea-growing districts, but little of the tea comes to this port. Large quantities of a coarse acrid leaf called tea, and sometimes wild tea, are brought down the river to Ichang, and thence sent to small towns below; it is very cheap, and used only by the poor.

The values of the tea exports from Kiukiang in the years 1877, 1878, 1879 respectively were: 2,333,094*l.*, 2,333,784*l.*, 2,005,086*l.*; the quantities of the various kinds were: black, 176,498 *piculs*, 206,798, 190,150; green, 51,476, 40,316, 40,368; brick, 7452, 11,285, 14,796; leaf, 480, 516, 510; dust, 9236, 9181, 3663.

Tea forms the principal export from Macao, being grown in the neighbouring district of Tayshan. It is brought down in a half-prepared state in bags, and undergoes the necessary firing and manipulation at Macao, where it is packed in boxes, and shipped by river steamer to Hong Kong, the bulk of it finding its way thence to London, a little going also to Australia and New York. The export in 1879 was about 9,000,000 lb. Ningpo exported of green tea, 145,018 *piculs* in 1877, 103,006 in 1878, 127,821 in 1879.

The exports of tea from Shanghae, in *piculs* of 133⅓ lb., in 1879 were:—

Destination.	Black.			Leaf.	Dust.	Brick.	Japan, Uncoloured.	Green.						Japan, Coloured.
	Congou.	Oolong.	Total.					Young Hyson.	Hyson.	Twankay.	Imperial.	Gun-powder.	Total.	
Great Britain ..	193,390	..	193,389	..	3,908	..	..	16,319	7,585	39	2,430	20,994	47,367	446
Hong Kong	1,521	..	1,521	..	..	357	..	5	53	..	11	13	82	
India	442	..	443	..	..	..	..	..	8,244	..	..	..	8,214	
United States ..	15,019	..	15,019	..	..	..	..	48,227	6,431	848	13,619	52,892	122,019	311
France	444	..	444	..	..	..	..	13	18	..	..	9	40	
Other Europe ..	31	..	31											
Russia (Odessa) ..	695	..	695											
Russian Manchuria	2,748	892	3,640	..	..	7,323								
Japan	98	[illegible]	102	..	..	..	..	..	43	..	..	..	43	
Egypt, Colonies, &c.	453	..	453	..	..	..	..	..	9	..	..	..	9	
Straits	7	..	7											
Total foreign ..	214,848	895	215,744	..	3,908	7,680	..	64,564	22,383	887	16,060	73,908	177,804	757
„ Chinese ports	125,607	..	125,607	640	1,412	146,257	91	6	69	..	..	69	146	4
Grand total ..	340,455	895	341,351	640	5,320	153,937	91	64,570	22,452	887	16,060	73,977	177,950	761

About 18,000,000 lb. of black tea were also sent to Siberia.

The exports of black tea from Tamsuy and Kelung were 69,231 *piculs* in 1877, 80,261 in 1878, and 85,033 in 1879. The northern end of the island of Formosa could easily treble its present out-put. Formosan teas are gaining favour in America, but not in England.

Wenchow exported of Congou and unfired teas respectively, 350 and 331 *piculs* in 1878, and 728 and 251 in 1879.

The exports of tea from Wuhu in 1877, 1878, 1879 were: black, ½, 383, and 2154 *piculs*; green, 3162, 707, and 232. The supplies came chiefly from Ching Hsien, T'ai-p'ing Hsien, and the hills near Ning-kwo-fu. The famous tea of Lin-an-chow, in N. Anhui, which is renowned for its delicate flavour, and accounted the second best in China, remains untouched by the foreign buyer, and the whole production, some 300,000 *piculs* yearly, is prepared exclusively for the Chinese market.

India.—The production of Indian tea has rapidly increased since 1860, when our imports first reached 1,000,000 lb. In 1870, our imports were 13,000,000 lb.; in 1880, 45,000,000 lb., value 3,000,000*l.*; and the figures will soon be 50,000,000 lb. a year. About 200,000 acres are covered with tea-bushes, 15,000,000*l.* of capital invested, and over 250,000 persons employed. Assam occupies the first place. In the Kámrúp district, in 1874, the area was returned at 2687 acres, and the out-turn from 24 plantations was 321,962 lb.; these figures are far short of the totals. In the Darrang district, in 1874, the area under tea was 3856 acres, the out-turn being 1,008,077 lb. In 1872, the black teas produced were:—Congou, 36,659 lb.; Pekoe, 371,233; Broken Pekoe, 175,766; Pekoe Souchong, 215,605; Souchong, 114,659; Broken Souchong, 55,691; Pekoe fannings, 14,188; broken tea, 65,213; fannings, 135,845; green, 6000 lb. In the Nowgong district in 1872, 1278½ acres were occupied by mature plants, and a total of 12,319 acres was selected for tea culture. The yield was:—Congou, 20,000 lb.; Congou and Souchong, 9500; Souchong, 28,276; Pekoe, 217,794; Pekoe and broken Pekoe, 47,604; broken Pekoe, 4450; broken Pekoe and fannings, 15,397; fannings, 13,120; total, 370,901; average yield per acre of mature plants, 288 lb. In the Sibsagar district, which is second only to Cachar among all the tea-growing districts of India, the area under tea in 1874 was 22,573 acres; the total out-turn, 4,528,329 lb. The total area taken up for tea to the end of 1874 was 108,050 acres. The approximate yield in 1872 was:—Congou, 210,026 lb.; Pekoe, 1,006,874; Pekoe Souchong, 85,266; Souchong, 526,150; fannings, 866,784; total, 3,199,500 lb. The average yield per acre of mature plants was 238 lb. The exports from Lakhimpur in 1871 were:—546¾ tons, 43,650*l.* The area in 1874 was 89,370 acres (11,680 in bearing); total out-turn, 1,811,920 lb.

Sylhet, in 1874, had 19,190 acres in tea-gardens, of which 5297 were actually under cultivation. The out-turn was 567,567 lb. In 1876, it was estimated at 655,600 lb. The average per acre of mature plants (upwards of 2 years) is 111 lb., as against 200 lb. for the whole province. Sylhet and Cachar combined gave 4,600,000 lb. in 1870, and 9,000,000 lb. in 1878. Darjeeling, the Terai, and the Dooars had 144 gardens, yielding 7,530,940 lb. in 1878, and 152 gardens, affording 5,538,040 lb. in 1879. Chittagong produced about 1,000,000 lb. in 1878; and other outlying districts, about 500,000 lb.

Japan.—The tea-plant grows well here, and tea forms one of the chief exports to foreign countries, not even excluding China itself. The best leaf comes from the neighbourhood of Uji, in the province of Yamashiro, to the S.-E. of Kiôto; but tea is also largely produced in the fertile district in the east of the main island, and exported from Yokohama. Japanese tea is driving Chinese green tea from the American market; 11,000,000 lb. went there in 1879.

Java.—The tea-gardens of Java are situated mostly in the Batavian department of Buitenzorg, and in the Preanger Regencies. The production of tea was stated at 5,700,000 lb. in 1879. The Chinese variety is the only one grown to any extent; trials are being made with the Assam shrub, but have not yet had any practical result. The Java teas are somewhat similar to Assams, and are readily saleable in England, where they are chiefly used for mixing with Indian. The 1879 crop was exported thus:—England, 31,814 *piculs* and cases; Holland, 31,382; Persian Gulf, 930; Australia, 440; Japan, 100; Singapore, 68.

Adulterants and Substitutes.—The adulterants of tea are exceedingly numerous, and the Chinese manifest wonderful skill in this direction. Among the first class of adulterants, viz. foreign leaves, are included those of the ash, plum, dog-rose, *Rhamnus spp.*, *Rhododendron spp.*, and *Chrysanthemum spp.*, as well as tea-stalks and paddy-husks, all for the purpose of increasing the bulk; also the scented flowers of *Olea fragrans*, *Chloranthus inconspicuus*, *Aglaia odorata*, *Camellia Sasanqua*, *Gardenia florida*, *Jasminum Sambac* and other species, to impart fragrance to inferior samples. Sometimes the true tea is almost replaced by a factitious compound known as "lie-tea," composed of a little tea-dust, blended with foreign leaves, sand, and magnetic iron by means of a solution of starch, and coloured with graphite, turmeric, indigo, Prussian blue, or China clay, according to the kind of tea it is intended to simulate. Mineral adulterants are used to give weight and colour. In addition to those employed in the fabrication of lie-tea, are soapstone and gypsum. The adulteration practised after the arrival of the tea in this country embraces the substitution or admixture of the leaves of the beech, box, elm, hawthorn, horse-chestnut, fancy oak, plane, bastard plane, poplar, sloe, sycamore, and willow, and artificial colouring by means of cutch, indigo, Dutch and rose pinks, sulphate of iron, Venetian red, chromates of lead and potash, carbonates of copper, lime and magnesia, arsenite of copper, and Prussian blue.

Besides the well-known varieties or species of *Thea*, two new kinds have recently been described by Consul E. Colborne Baber. One is grown by the monks on Mount Omi (Ngomi), and gives an infusion tasting like coarse Congou highly sweetened with brown sugar. The other is found wild in the uninhabited wilderness west of Kiating and south of Yachow, at 6000 ft. and upwards, notably on the Hwang-mu-chang plateau, among the gorges of the Tung river; it is a shrub 15 ft. high with a stem 4 in. thick; every part except the root is used in the infusion, which has a buttery flavour. A third new species is reported from the neighbourhood of Trebizonde where the leaves are picked and sun-dried, and sent in large quantities to Persia.

The name "tea" has been popularly applied to many other plants, the principal being as follows:—Abyssinian or Arabian (*Catha* [*Celastrus*] *edulis*), the leaves of which are used by the Arabs in the preparation of a beverage possessing similar properties to tea; Appalachian (*Viburnum cassinoides* and *Prinos glaber*), the infusion of the latter resembling maté; Australian (*Leptospermum* and *Melaleuca spp.*): the leaves of *L. lanigerum*, of Tasmania and S.-E. Australia, were used as tea by the early colonists, for *Melaleuca* see Cajuput-oil, p. 1418; Bencoolen (*Glaphyria nitida*), whose leaves are infused like tea by the Malays; blue mountain or golden rod (*Solidago odora*); Botany Bay (*Smilax glyciphylla*), in Australia; Bourbon or Faham (*Angræcum fragrans*), largely grown in Bourbon, and the leaves made into an aromatic tea-like beverage; Brazilian (*Stachytarpha* [*Stachytarpheta*] *jamaicensis*), whose leaves are said to possess medicinal virtues, being sold in Austria as "Brazilian tea," and sometimes used to adulterate tea; bush (*Cyclopia genistoides*), the leaves of which have a tea-like fragrance, and are used in infusion at the Cape to promote expectoration; Canary (*Sida canariensis*); Carolina (*Ilex vomitoria*); coffee-leaf (see Coffee, p. 707); gout (*Cordia globosa*), in the W. Indies; Jesuits' (*Psoralea glandulosa*), the *culen* of Chili, whose leaves give a not very aromatic infusion, and are more useful as a vermifuge and stomachic; Labrador (see Narcotics—Ledum, p. 1308); lemon-grass (see p. 1421), the leaves of which are used like tea in the interior of India; Malay (*Eugenia variabilis*), see also Bencoolen; Mexican (*Ambrina ambrosioides*), used medicinally as a vermifuge and anti-spasmodic (also *Psoralea glandulosa*); mountain (*Gaultheria procumbens*), whose leaves are used to flavour tea, or as a substitute (see also Wintergreen-oil, p. 1431); New Jersey (*Ceanothus americanus*), the leaves of which were used as tea during the American War of Independence; New Zealand (*Leptospermum scoparium*), allied to and used like Australian tea; Oswego (*Monarda didyma*), so called from the leaves being sometimes used as tea in America; paigle- (pagle, peagle) tea, an infusion of the dried blossoms of the cowslip (*Primula veris*), possessing narcotic properties, and drunk in some counties of England; Paraguay-tea or maté is an infusion of the leaves of *Ilex paraguayensis* and probably *I. Gongonha* and *I. theezans*, which are prepared by roasting the branches on hurdles over a wood fire, and then beating the dried leaves to powder by sticks on a hard floor; 3 kinds are distinguished: *caa-cuys*, the half-expanded leaf-buds; *caa-miri*, the leaf deprived of midrib and veins without roasting; *caa-guaza* or *yerva de polos*, the whole leaf with the petioles and small branches roasted; the consumption in S. America is 8 million lb. yearly; saloop-tea is an infusion of sassafras (called "sassafras-tea") flavoured with milk and sugar, and said to be formerly drunk by the working classes in London; South Sea, see Carolina; sweet, see Botany Bay; theezan-tea is an infusion of the leaves of the *tia* (*Sageretia theezans*), native of Penang, the Philippines, and S. China, and said to be sometimes used as tea by the poorer Chinese; W. Indian (*Capraria biflora*); wild (*Amorpha canescens*).

Imports, Exports, and Values.—Our imports of tea in 1880 were:—From China, 158,195,142 lb., 8,349,699*l.*; Bengal and Burma, 44,437,406 lb., 3,032,354*l.*; Holland, 2,426,738 lb., 120,738*l.*; Bombay and Sind, 618,062 lb., 34,840*l.*; United States, 335,804 lb., 19,313*l.*; Straits Settlements, 242,222 lb., 13,975*l.*; Japan, 213,804 lb., 11,552*l.*; Ceylon, 150,395 lb., 10,132*l.*; Madras, 82,643 lb., 5728*l.*; other countries, 269,284 lb., 15,067*l.*; total, 206,971,570 lb., 11,613,398*l.*; retained for home consumption, 158,570,842 lb., 3,964,290*l.*

Our exports in 1880 were:—To Germany, 22,713,650 lb., 1,394,008*l.*; British N. America, 6,257,384 lb., 406,943*l.*; Russia, 5,557,571 lb., 333,656*l.*; Holland, 3,176,343 lb., 187,026*l.*; Denmark, 832,951 lb., 55,481*l.*; Chili, 727,421 lb., 41,251*l.*; Portugal, Azores, and Madeira, 662,033 lb., 57,489*l.*; United States, 652,179 lb., 38,014*l.*; Channel Islands, 611,253 lb., 38,341*l.*; Morocco, 432,629 lb., 38,318*l.*; France, 424,042 lb., 33,371*l.*; Brazil, 395,572 lb., 33,070*l.*; Turkey, 348,832 lb., 22,593*l.*; other countries, 1,802,986 lb., 124,007*l.*; total, 44,594,846 lb., 2,803,568*l.*

The approximate London market values per lb. of teas in bond (duty 6*d.* a lb.) are:—Congou: brown leaf siftings, 4–10*d.*, ordinary to leafy, 7–10*d.*, good ordinary to middling, 7½–11*d.*, ditto export kinds, 8¼–11½*d.*, fair to medium, 9–17*d.*; Kaisow, 2nd class, 14–20*d.*, 1st to finest, 18–27*d.*; black leaf, common, 7¼–14½*d.*, good common, 8¼–32½*d.*, fair to medium, 9½–17*d.*; Oopack and Moning, 8–27*d.*; ditto fine to finest, 19–30*d.*; Tayshan, 7–18*d.*; Ning Yong and Oolong, 8–24*d.*; Souchong, common to good, 8¼–20*d.*, fine to finest, 12–24*d.*; Flowery Pekoe, 12–19*d.*, fine to finest, 19–40*d.*; Caper, scented, 6½–15*d.*, fine to finest, 10½–21*d.*; Orange Pekoe, scented, 6–18*d.*, fine to finest, 12–24*d.*; Twankay, 4½–13*d.*; Hyson, common, 6¼–14*d.*, fair to fine, 10–27*d.*, finest, 21–42*d.*; Young Hyson, common, 5½–14*d.*, good to finest, 9-30*d.*; Imperial, 6–15*d.*, good to superior, 10–22*d.*; Gunpowder, 7–19*d.*, good to finest, 12–42*d.*; Canton, 8-12*d.*; Japan, uncoloured, 8–16*d.*; Indian: broken, 8½–28*d.*, Congou, 9–16*d.*, Souchong, 9–24*d.*, Pekoe Souchong, 12–32*d.*, Pekoe, 10½–38*d.*; Flowery Pekoe, 18–45*d.*

Bibliography.—S. Ball, 'Cultivation and Manufacture of Tea in China, &c.' (London: 1848); R. Fortune, 'Tea Districts of India and China' (London: 1853); W. Nassau Lees, 'Tea Cultivation in India' (London: 1863); 'Papers on Tea Industry in Bengal' (Calcutta: 1873); A. H. Hassall, 'Food: its Adulterations' (London: 1876); L. & S. Ritter von Fries, 'Thee-cultur und -handel in China' (Vienna: 1878); E. Money, 'Cultivation and Manufacture of Tea' (3rd ed., London and Calcutta: 1878); W. Cochran, 'Capabilities of New Zealand for Tea Culture' (Jour. Soc. Arts., Vol. xxx. No. 1524, London: 1882); J. H. Haworth, 'Information and Advice for Tea-planters' (Jour. Agri.-Horti. Soc. Ind., Vol. xiv., Calcutta: 1865); also the following papers in the Jour. Agri.-Horti. Soc. Ind., on Tea Culture, &c., in:—Kumaon, Gurhwal, and Deyra Doon, i. 288, ii. 323, iv. 173, v. app. 146, vi. 81, app. 14. viii. app. 1; Chittagong, ii. app. 408; Assam, ii. 337, iii. 1, 61, app. 102, v. 79, app. 132, xiii. pt. i. 31; Java, v. 162, 206, vi. 72, vii. 292; Darjeeling, vi. 123, vii. 31, viii. 91, xiv. sup. p. xxxvii.; Cachar, ix. 201, xiv. sup. p. i.; Sylhet, ix. 207, 342; Himálayas, xiv. pt. ii. 119.

(See Beverages—Tea.)

TIMBER (Fr., *Bois d'œuvre*; Ger., *Nutzholz*).

Properly speaking, the term "timber" is confined to those kinds of wood which are eligible for building purposes; but in the present article, it will be extended to embrace all useful woods, except such as have been already described under Drugs (Quassia, p. 820); Dyestuffs (Barwood, p. 855; Brazil-wood, p. 856; Camwood, p. 856; Logwood, p. 862; Sanders-wood, p. 867; Sapan-wood, p. 867); Perfumes (Sandal-wood, pp. 1527–8); and Tannin (Quebracho, p. 1988). They will be arranged in alphabetic order. The terms used in describing the characters of the various woods may be explained once for all. The "cohesive force" is the weight required to pull asunder a bar of the wood in the direction of its length; the figures denoting the strength, toughness, and stiffness, are in comparison with oak, which is taken as the standard, and placed at 100 in each case; the "crushing-force" is the resistance to compression; the "breaking-weight" is the weight required to break a bar 1 in. sq. supported at two points 1 ft. apart, and the weight suspended in the middle.

For more detailed information regarding the peculiar properties of building-woods, and the many methods of preserving timber, the reader is referred to the new edition of Tredgold's Carpentry, by Hurst, and to other works quoted in the Bibliography at the end of this article; a copious list of books on forestry will be found in Daydon Jackson's 'Vegetable Technology.'

Acacia or American Locust-tree (*Robinia pseudo-acacia*).—This beautiful tree, of considerable size and very rapid growth, inhabits the mountains of America from Canada to Carolina, its trunk attaining the mean size of 32 ft. long and 23 in. diam. The seasoned wood is much valued for its durability, surpassing oak. It is admirable for building, posts, stakes, palings, treenails for ships, and other purposes. Its weight is 49–56 lb. a cub. ft.; cohesive force, 10,000–13,000 lb.; and the strength, stiffness, and toughness of young unseasoned wood are respectively 95, 98, and 92.

Alder (*Alnus glutinosa*).—This small tree inhabits wet grounds and river-banks in Europe and Asia, seldom exceeding 40 ft. high and 24 in. diam. The wood is extremely durable in water and wherever it is constantly wet; but it soon rots on exposure to the weather or to damp, and is much attacked by worms when dry. It is soft, works easily, and carves well; but it is most esteemed for piles, sluices, and pumps, and has been much cultivated in Holland and Flanders for such purposes. Its weight is 34–50 lb. a cub. ft.; cohesive force, 5000–13,900 lb.; strength, 80; stiffness, 63; toughness, 101. It is one of the woods used in making gunpowder (see p. 882).

Alerce-wood (*Callitris quadrivalvis*).—This is the celebrated citrus-wood of the ancient Romans, the timber of the gum sandarach tree (see pp. 1681–2). The wood was esteemed above all others for roofing temples and for tables, and is employed in the cathedral of Cordova. Among the luxurious Romans, the great merit of the tables was to have the veins arranged in waving lines or spirals, the former called "tiger" tables and the latter "panther." Others were marked like the eyes on a peacock's tail, and others again appeared as if covered with dense masses of grain. Some of these tables were 4–4½ ft. diam. The specimens of the tree now existing in S. Morocco resemble small cypresses, and are apparently shoots from the stumps of trees that have been cut or burnt, though possibly their stunted habit may be due to sterility of soil. The largest seen by Hooker and Ball in 1878 were in the Ourika valley, and were about 30 ft. high. The stems of the trees swell out at the very base into roundish masses, half buried in soil, rarely attaining a diameter of 4 ft. It is this basal swelling, whether of natural or artificial origin, which affords the valuable wood, exported in these days from Algiers to Paris, where it is used in the richest and most expensive cabinet-work. The unique beauty of the wood will always command for it a ready market, if it be allowed to attain sufficient size, and the tree is certainly deserving of earnest attempt to naturalize it in the botanic gardens of some of our tropical colonies, before it becomes extinct at the hands of the apathetic Moors, who are wasting the wood for building and fuel.

Alerse (*Libocedrus tetragona*).—This is a Chilian tree, affording a timber which is largely used on the S. Pacific coast of America, and an important article of commerce. It gives spars 80–90 ft. long, and 800–1500 boards. Its grain is so straight and even that shingles split from it appear to have been planed.

Ash (*Fraxinus excelsior*).—The common ash is indigenous to Europe and N. Asia, and found throughout Great Britain. The young wood is more valuable than the old; it is durable in the dry, but soon rots by exposure to damp or alternate wetting, and is very subject to worm when felled in full sap. It is difficult to work and too flexible for building, but valuable in machinery, wheel-carriages, blocks, and handles of tools. The weight is 34–52 lb. a cub. ft.; cohesive force, 6300–17,000 lb.; strength, 119; stiffness, 89; toughness, 160.

Assegai-wood or Cape Lancewood (*Curtisia faginea*).—This tree, the *oomhlebe* of the African natives, gives a very tough wood, used for wheel-spokes, shafts, waggon-rails, spears, and turnery, weighing 56 lb. a cub. ft.

Beech (*Fagus sylvatica*).—The common beech inhabits most temperate parts of Europe, from

Norway to the Mediterranean, and is plentiful in S. Russia. It is most abundant in the S. and Midland counties of England, growing on chalky soils to 100 ft. high and 4–6 ft. diam. Wood grown in damp valleys becomes brittle on drying; it is very liable to destruction by worms, decays in damp situations, less in a dry state, but least of all when constantly under water. It is thus most useful for piles, and for knees and planking of ships. Its uniform texture and hardness make it very valuable for tools and common furniture. It is also used for carriage-panels and wooden tramways. Its weight is 43–53 lb. a cub. ft.; cohesive force, 6070–17,000 lb.; strength, 103; stiffness, 77; toughness, 138. (See Oils, p. 1378; Tar, p. 1683.)

Beech [American].—Two species of *Fagus* are common in N. America,—the white (*F. sylvestris*), and the red (*F. ferruginea*). The perfect wood of the former is frequently only 3 in. in a trunk 18 in. diam., and it is of little use except for fuel. The wood of the latter, which is almost exclusively confined to the N.-E. States, Canada, New Brunswick, and Nova Scotia, is stronger, tougher, and more compact, but so liable to insect attacks as to be little used in furniture; yet it is very durable when constantly immersed in water.

Birch (*Betula spp.*).—The common birch (*B. alba*) is less important as a source of wood than as affording an empyreumatic oil (see pp. 1417–8, 1684). Its wood is neither strong nor durable, but is easily worked, moderately hard, and of straight and even grain, rendering it useful for chair-making, cabinet-making, and light turnery. Memel exported by sea in 1880, 175,051 birch staves, value 340*l.*, and 45,596 logs, value 832*l.* 10*s.*

The American red birch (*B. rubra*) has similar uses. The black or cherry birch (*B. lenta* [*nigra*]) of N. America is superior to all others, and imported in logs 6–20 ft. long and 12–30 in. diam., for furniture and turnery. Quebec birch is worth 3*l.* 5*s.*–4*l.* 15*s.* a load.

Box (*Buxus sempervirens*).—The common evergreen box is a native of Europe as far as 52° N. lat., and is abundant in S. and E. France, Spain, Italy, the Black Sea coast, Persia, N. India, China, and Japan. For some years past, the supply of this important wood has diminished in quantity and risen in price. It is mainly derived from the forests of the Caucasus, Armenia, and the Caspian shores. The wood of the best quality comes from the Black Sea forests, and is principally shipped from the port of Poti. The produce of the Caspian forests, known in the trade as "Persian," used also to be exported through the Black Sea from Taganrog. This found its way, after the commencement of the Russo-Turkish war, viâ the Volga canal, to St. Petersburg. The produce of the Caspian forests is softer and inferior in quality to that of the Black Sea. It is a large article of trade with Russia, reaching Astrakhan and Nijni-Novgorod in the spring, and being sold during the fair. It recently amounted to 130,000 *poods* (of 36 lb.). True Caucasian boxwood may be said to be commercially non-existent, almost every marketable tree having been exported. The value of the yet unworked Abkhasian forests has been much exaggerated, many of the trees being either knotted or hollow from age, and most of the good wood having been felled by the Abkhasians previous to Russian occupation. The boxwood at present exported from Rostov, and supposed to be Caucasian, comes from the Persian provinces of Mazanderan and Ghilan, on the Caspian. Boxwood is characterized by excessive hardness, great weight, evenness and closeness of grain, light colour, and capacity for taking a fine polish. Hence it is very valuable for wood-engraving (see p. 1610), turning, and instrument-making. The Minorca box (*B. balearica*), found in several of the Mediterranean islands, and in Asia Minor, yields a similar but coarser wood, which probably finds its way into commerce.

The shipments of boxwood from Taganrog were 4681 tons in 1878, 2904 tons in 1879, and 1839 tons, 23,177*l.*, in 1880. The exports from Trebizonde were, in 1879, 702 cwt. to Turkey, and 7040 cwt. to Great Britain, total value 1161*l.*; in 1860, 541 cwt., 51*l.*, to Great Britain. Ghilan exported to Russia 8846*l.* worth in 1878, and 4444*l.* worth in 1879. Poti despatched 12,640 *poods* (of 36 lb.) in 1877–8. The approximate value of Turkey box is 6–20*l.* a ton.

Broadleaf or Almond (*Terminalia latifolia*).—This is a Jamaica tree, growing 60 ft. high to the main branches, and 3½–5 ft. diam. It is used for timbers, boards, shingles, and staves. Its weight is 48 lb. a cub. ft.; crushing-force, 7500 lb.; breaking-weight, 750 lb.

Bullet-tree (*Mimusops Balata*).—This tree is found in the W. Indies and Central America. Its wood is very hard and durable, and fitted for most outside work; it is used principally for posts, sills, and rafters. It warps much in seasoning, splits easily, becomes slippery if used as flooring, and is very liable to attacks of sea-worms. Its weight is 65½ lb. a cub. ft.; crushing-force, 14,330 lb. (See Resins—Balata, p. 1635, Chicle, 1639.)

Calophyllum. See Tamanu, p. 2021.

Cedar [Australian Red] (*Cedrela australis*).—This tree is a native of Australia, where it has been almost exterminated, the timber being found so useful in house-building (for joinery, doors, and sashes) and boat-building. Its weight is 35 lb. a cub. ft.; breaking-weight, 471 lb.

Cedar [Bermuda] (*Juniperus bermudiana*).—This species is a native of the Bermudas and Bahamas. Its wood much resembles that of Virginian Cedar, and is used for similar purposes, as well as for ship-building. It is extremely durable when ventilated and freed from sap-wood. It lasts 150–200 years in houses, and 40 years as outside ship-planking. It is difficult to get above 8 in. sq. Its weight is 46–47 lb. a cub. ft.

Cedar of Lebanon (*Abies Cedrus* [*Cedrus Libani*]).—This evergreen tree is a native of Syria, and probably Candia and Algeria. The trunk reaches 50 ft. high and 34–39 in. diam. The wood is said to be very durable, and to have been formerly extensively used in the construction of temples. It is straight-grained, easily worked, readily splits, and is not liable to worm. Its weight is 30–38 lb. a cub. ft.; cohesive force, 7400 lb. a sq. in.; strength, 62; stiffness, 28; toughness, 106. (See Oils, p. 1419.)

Cedar [New Zealand] (*Libocedrus Bidwillii* and *L. Doniana*).—Of these species, the latter, the *kawaka* of the natives, is a fine timber tree 60–100 ft. high, yielding heavy, fine-grained wood, useful in fencing, house-blocks, piles, and sleepers. It weighs 30 lb. a cub. ft.; breaking-weight, 400 lb. The first species gives a soft, porous wood, useless for timber purposes.

Cedar [Virginian Red] (*Juniperus virginiana*).—This small tree (45–50 ft. high and 8–18 in. diam.) inhabits dry rocky hillsides in Canada, the United States, and W. Indies, and flourishes in Britain. The wood is much used in America for wardrobes, drawers, boxes, and furniture, being avoided by all insects on account of its strong odour and flavour. It is light, brittle, and nearly uniform in texture. It is very extensively employed for covering graphite pencils, being imported in pieces 6–10 in. sq. It weighs 40½ lb. a cub. ft. (See Oils, p. 1419.)

Cedar [W. Indian or Havanna] (*Cedrela odorata*).—This tree is a native chiefly of Honduras, Jamaica, and Cuba, having a stem 70–80 ft. high and 3–5 ft. diam., and exported in logs up to 3–4 ft. sq. Its wood is soft, porous, and brittle, and used chiefly for cigar-boxes and the inside of furniture. It makes durable planks and shingles. Its weight is 36 lb. a cub. ft.; crushing-weight, 6600 lb.; breaking-weight, 400 lb. Costa Rica exported from San José, in 1875, 81 boards, 113 planks, and 7306 logs of cedar; in 1878, 365 planks and 645 logs. The exports from British Honduras were 18,923 ft. in 1876, 77,582 in 1877, 87,129 in 1878. The approximate London market values are 4–5¼*d.* a ft. for Cuba cedar, and 4–5¼*d.* for Honduras, &c.

Cedar Boom (*Widdringtonia juniperoides*).—This tree is found in N. and W. Cape Colony, and its wood is used for floors, roofs, and other building purposes, but will not stand the weather.

Chestnut (*Castanea vesca*).—This, the sweet or Spanish chestnut, is said to be a native of Greece and W. Asia, but grows wild also in Italy, France, Spain, N. Africa, and N. America. It lives to 1000 years, but reaches its prime at about 50, when the stem may be 40–60 ft. long and 3–6 ft. diam. The wood is hard and compact: when young, it is tough and flexible, and as durable as oak; when old, it is brittle and shaky. It does not shrink or swell so much as other woods, and is easier to work than oak; but soon rots when built into walls. It is valued for hop-poles, palings, gate-posts, stakes, and similar purposes. Its weight is 43–54 lb. a cub. ft.; cohesive force, 8100 lb.; strength, 68; stiffness, 54; toughness 85. (See Nuts, p. 1352; Tannin, p. 1982.)

Cypress (*Cupressus sempervirens*).—This tree is abundant in Persia and the Levant, and cultivated in all countries bordering the Mediterranean, thriving best in warm sandy or gravelly soil, and reaching 70–90 ft. high. Its wood is said to be the most durable of all. For furniture, it is stronger than mahogany, and equally repulsive to insects. In Malta and Candia, it is much used for building. It weighs about 40–41 lb. a cub. ft.

Deal [White], White Fir, or Norway Spruce (*Abies excelsa*).—This tree inhabits the mountainous districts of Europe, and extends into N. Asia, being especially prevalent in Norway. It runs to 80–100 ft. high, and about 2–3 ft. max. diam. The tree requires 70–80 years to reach perfection, but is equally durable at all ages. It is much imported in spars and deals, the latter about 12 ft. long, 3 in. thick, and 9 in. wide. The wood glues well, and is very durable while dry, but much more knotty than Northern Pine. It is fine-grained, and does well for gilding on, also for internal joinery, lining furniture, and packing-cases. A principal use is for scaffolds, ladders, and masts, for which purpose it is largely imported from Norway in entire trunks, 30–60 ft. long, and 6–8 in. max. diam. It is shipped from Christiania, Friedrichstadt, Drontheim, Gottenburg, Riga, Narva, St. Petersburg, &c. Christiania deals and battens are reckoned best for panelling and upper floors; Friedrichstadt have small black knots; lowland Norway split and warp in drying; Gottenburg are stringy and mostly used for packing-cases; Narva are next in quality to Norway, then Riga; St. Petersburg shrink and swell even after painting. The wood is generally light, elastic, tough, easily worked, and extremely durable when properly seasoned. It weighs 28–34 lb. a cub. ft.; cohesive force, 8000–12,000 lb. a sq. in.; strength, 104; stiffness, 104; toughness, 104. (See Rosin, p. 1680; Pine-oils, p. 1408; Turpentine-oils, p. 1431; Pitch, pp. 1678–9; Tar, p. 1684.)

Deodar (*Cedrus Deodara*).—This tree is found in the Himálayas at 5000–12,000 ft., and on the higher mountains from Nepal to Kashmir, measuring 150–200 ft. high, and over 30 ft. circ. Its wood is extremely valuable for all carpentry, and most generally used in the Punjab for building. Its weight is 37 lb. a cub. ft.; breaking-weight, 520 lb.

Dogwood.—The American dogwood (*Cornus florida*) is a tree 30 ft. high, common in the woods of many parts of N. America. Its wood is hard, heavy, and close-grained, and largely used locally for tool-handles; it has been imported into England with some success as a substitute for box in making shuttles for textile machinery.

The black dogwood or alder buckthorn (*Rhamnus Frangula*) is abundant in Asia Minor, and affords one of the best wood charcoals for gunpowder-making (see p. 882). Its berries probably contribute to the yellow dyestuff known as Persian berries (see p. 864).

Doorn Boom or Kameel Boom (*Acacia horrida*).—This tree is a native of S. Africa, and affords small timber used for fencing, spars, fuel, and charcoal. (See Cape Arabic, p. 1632.)

Ebony (*Diospyros spp.*).—The best and most costly kind of ebony, having the blackest and finest grain, is the wood of *D. reticulata*, of Mauritius. Two E. Indian species, *D. Melanoxylon* and *D. Ebenaster*, also contribute commercial supplies, and another kind is obtained from *D. Ebenum*, of Ceylon. The heart-wood of the trunk of these trees is very hard and dense, and is largely used for fancy cabinet-making, mosaic work, turnery, and small articles. The approximate London market values are 5–20*l.* a ton for Ceylon, and 3–12*l.* for Zanzibar, &c.

Elm (*Ulmus spp.*).—Five species of elm are now grown in Britain:—The common rough-leaved (*U. campestris*) is frequent in scattered woods and hedges in S. England, and in France and Spain, attaining 70–80 ft. high and 4 ft. diam. Its wood is harder and more durable than the other kinds, and is preferred for coffins, resisting moisture well. The cork-barked (*U. suberosa*) is common in Sussex, but the wood is inferior. The broad-leaved wych-elm or wych-hazel (*U. montana*) is most cultivated in Scotland and Ireland, reaching 70–80 ft. high and 3–4½ ft. diam. The smooth-leaved wych-elm (*U. glabra*) is abundant in Essex, Hereford, the N. and N.-E. counties of England, and in Scotland, growing to a large size. The wood is tough and flexible, and preferred for wheel-naves. The Dutch elm (*U. major*), the smallest of the five, is indigenous to Holland; its wood is very inferior. Elm-trunks average 44 ft. long and 32 in. diam. The wood is very durable when perfectly dry or constantly wet. It is not useful for general building, but makes excellent piles, and is used in wet foundations, waterworks, and pumps; also for wheel-naves, blocks, keels, and gunwales. It twists and warps in drying, shrinks considerably, and is difficult to work; but is not liable to split, and bears the driving of bolts and nails very well. Its weight is 34–50 lb. a cub. ft.; cohesive force, 6070–13,200 lb.; strength, 82; stiffness, 78; toughness, 86.

These species of elm are indigenous to N. America, and have similar uses to the European kinds:—The common American (*U. americana*) grows in low woods from New England to Canada, reaching 80–100 ft. high; its wood is inferior to English. The Canada rock or mountain (*U. racemosa*) is common to Canada and the N. States; the wood is used in boat-building, but is very liable to shrink, and gets shaky by exposure to sun and wind; its weight is 47–55 lb. a cub. ft. The slippery (*U. fulva*) gives an inferior wood, though much used for various purposes. Quebec elm is valued at 4–5*l.* a load.

Fir [Silver] (*Picea pectinata*).—This large tree (100 ft. high, and 3–5 ft. diam.) is indigenous to Europe, Asia, and N. America, growing in British plantations. It is said to attain its greatest perfection in this country at 80 years. The wood is of good quality, and much used on the Continent for carpentry and ship-building. Floors of it remain permanently level. It is liable to attacks of the worm, and lasts longer in air than in water. It weighs about 25½ lb. a cub. ft.

Greenheart or Bibiri (*Nectandra Rodiœi* [*leucantha*]).—This celebrated ship-building wood is a native of British Guiana, and has been largely exported from Demerara to English dockyards. It gives balks 50–60 ft. long without a knot, and 18–24 in. sq., of hard, fine-grained, strong, and durable wood. It is reputed proof against sea-worms, and placed in the first class at Lloyd's; it is very difficult to work, on account of its splitting with great force. Its weight is 58–65 lb. a cub. ft.; crushing-weight, 12,000 lb.; breaking-weight, 1424 lb. (See Starch, p. 1823.)

Gum [Blue] (*Eucalyptus Globulus*).—This Australian and Tasmanian tree is of rapid growth, and often reaches 150–300 ft. high and 10–20 ft. diam. Its wood is hard, compact, difficult to work, and liable to split, warp, and shrink in seasoning. It is used for general carpentry and wheel-spokes. Its weight is 60 lb. a cub. ft.; crushing-force, 6700 lb.; breaking-weight, 550–900 lb. (See Eucalyptus-oils, p. 1420; Kino, p. 1668; Tannin, p. 1993.)

Gum [White or Swamp] (*E. viminalis*).—This tree is found chiefly in Tasmania, and a variety called the Tuvart occurs in W. Australia. The wood is valued for its great strength, and is sometimes used in ship-building, but more in house-building, and for purposes where weight is not an objection. It is sound and durable, shrinks little, but has a twisted grain, which makes it difficult to work. Its weight is about 70 lb. a cub. ft.; crushing-force, 10,000 lb.; breaking-weight, 730 lb.

Hickory or White Walnut (*Carya* [*Juglans*] *alba*).—There are about a dozen species of hickory, natives of N. America, forming large forest trees. Their timber is coarse-grained, and very strong, tough, and heavy; but is unsuited for building, as it does not bear exposure to the weather, and is much attacked by insects. It is extensively used where toughness and elasticity are required, such as for barrel-hoops, presses, handles, shafts and poles of wheel-carriages, fishing-rods, and even light furniture. The most important is the shell-bark, scaly-bark, or shag-bark (*C. alba*), common throughout the Alleghanies from Carolina to New Hampshire, growing 80–90 ft. high and 2–3 ft. diam. (See Nuts, p. 1358; Oils, p. 1391.)

Ironbark (*Eucalyptus resinifera*).—This rugged tree is found in most parts of the Australian continent, frequently reaching 100–150 ft. high and 3–6 ft. diam., the usual market logs being 20–40 ft. long and 12–18 in. sq. Its wood is straight-grained, very dense, heavy, strong, and durable, but very difficult to work. It is liable to be shaky, and can only be employed with advantage in stout planks or large scantlings. Its weight is 64½ lb. a cub. ft.; crushing-force, 9921 lb.; breaking-weight, 1000 lb.

Ironwood [Cape] (*Olea undulata*).—This S. African wood, the *tambooti* or *hooshe* of the natives, is very heavy, fine-grained, and durable, and is used for waggon-axles, wheel-cogs, spokes, telegraph-poles, railway-sleepers, and piles. This is the "black" ironwood. The "white" (*Vepris lanceolata*) is used for similar purposes.

Jack, or Ceylon Mahogany (*Artocarpus integrifolia*).—This useful tree is a native of the E. Archipelago, and is widely cultivated in Ceylon, S. India, and all the warm parts of Asia, mainly as a shade-tree for coffee and other crops. Its wood is in very general use locally for making furniture; it is durable, and can be got in logs 21 ft. long and 17 in. diam. Its weight is 42 lb. a cub. ft.; breaking-weight, 600 lb.

Jack [Jungle], or Anjilli (*A. hirsuta*).—This species is remarkable for size of stem, and is found in Bengal, Malabar, and Burma. Its wood is strong and close-grained, and considered next in value to teak for ship-building. Its weight is 38–49 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; breaking-weight, 740 lb.

Jarrah, Australian Mahogany, or Flooded or Red Gum (*Eucalyptus marginata*).—This tree attains greatest perfection in W. Australia, reaching 200 ft. high. Its wood is hard, heavy, close-grained, and very durable in salt and fresh water, if cut before the rising of the sap. It is best grown on the hills. It resists sea-worms and white ants, rendering it specially valuable for ships, jetties, railway-sleepers and telegraph-posts, but shrinks and warps considerably, so that it is unfit for floors or joinery. Logs may be got 20–40 ft. long and 11–24 in. sq. Its weight is 62½ lb. a cub. ft.; crushing-force, 7000 lb.; breaking-weight, 500 lb.

Kanyin (*Dipterocarpus alatus*).—This magnificent tree is found chiefly in Pegu and the Straits, reaching 250 ft. high. Its wood is hard and close-grained, excellent for all house-building purposes, but not durable in wet. Its weight is 45 lb. a cub. ft.; breaking-weight, 750 lb.

Another species (*D. turbinatus*), found in Assam, Burma, and the Andamans, is similar, and much used by the natives in house-building.

Kauri, Cowrie, or Pitch-tree (*Dammara australis*).—This gigantic conifer is a native of New Zealand, growing 80–140 ft. high, with a straight clean stem 4–8 ft. diam. The wood is close, even, fine-grained, and free from knots. It is chiefly used and well adapted for masts and spars; also for joinery, as it stands and glues well, and shrinks less than pine or fir. But it buckles and expands very much when cut into narrow strips for inside mouldings. Its weight is 35–40 lb. a cub. ft.; cohesive force, 9600–10,960 lb. a sq. in. (See Resins, p. 1666.)

Larch [American Black], Tamarak, or Hackmatack (*Larix pendula*).—This tree ranges from Newfoundland to Virginia, reaching 80–100 ft. high, and 2–3 ft. diam. The wood is said to nearly equal that of the European species.

Larch [Common or European] (*L. europæa*).—This species is a native of the Swiss and Italian Alps, Germany, and Siberia, but not of the Pyrenees nor of Spain. The Italian is most esteemed, and has been considerably planted in England. The tree grows straight and rapidly to 100 ft. high. The wood is extremely durable in all situations, such as posts, sleepers, &c., and is preferable to pine, pinaster or fir for wooden bridges. But it is less buoyant and elastic than Northern Pine, and boards of it are more apt to warp. It burns with difficulty, and makes excellent ship-timber, masts, boats, posts, rails, and furniture. It is peculiarly adapted for staircases, doors, and shutters. It is more difficult to work than Northern Pine, but makes a good surface, and takes oil or varnish better than oak. The liability to warp is said to be obviated by barking the trees while growing in spring, and cutting in the following autumn, or next year; this is also said to prevent dry-rot. The wood weighs 34–36 lb. a cub. ft.; cohesive force, 6000–13,000 lb.; strength, 103; stiffness, 79; toughness, 134. (See Venice Turpentine, p. 1691.)

Lignum-vitæ (*Guaiacum officinale*).—This tree grows chiefly on the S. side of Jamaica, and affords one of the hardest and heaviest woods, extremely useful for the sheaves and blocks of pulleys, for which purpose it should be cut with a band of sap-wood all round, to prevent splitting. Its weight is 73 lb. a cub. ft.; crushing-weight, 9900 lb. The exports of lignum-vitæ from San Domingo in 1880 were:—164 tons to Great Britain, 25 tons to France, 700 tons to Germany, 10 tons to Italy, 239 tons to the United States, 41 tons to the W. Indies; total 1149 tons. The approximate London market value is 4–10*l.* a ton. (See Drugs, p. 816; Resins, p. 1651.)

Locust-tree (*Hymenæa Courbaril*).—This tree is a native of S. America, and is found also in Jamaica. Its wood is hard and tough, and useful for house-building. Its weight is 42 lb. a cub. ft.; crushing-force, 7500 lb.; breaking-weight, 750 lb. (See Jutahy-seca, p. 1666.)

Mahogany (*Swietenia Mahogani*).—This tree is indigenous to the W. Indies and Central America. It is of comparatively rapid growth, reaching maturity in about 200 years, and the trunk exceeding 40–50 ft. long and 6–12 ft. diam. The wood is very durable in the dry, and not liable to worms. Its costliness restricts its use chiefly to furniture; it has been extensively employed in machinery for cotton-mills. It shrinks very little, warps and twists less than any other wood, and glues exceedingly well. It is imported in logs: those from Cuba, Jamaica, San Domingo, known as "Spanish," are about 20–26 in. sq. and 10 ft. long; those from Honduras, 2–4 ft. sq. and 12–14 ft. long. The weight is 35–53 lb. a cub. ft.; the cohesive force is 7560 lb. in Spanish, and 11,475 lb. in Honduras; the strength, stiffness, and toughness are respectively 67, 73, and 61 in Spanish, and 96, 93, and 99 in Honduras.

The tree attains its greatest development and grows most abundantly between 10° N. lat. and the Tropic of Cancer, flourishing best on the higher crests of the hills, and preferring the lighter soils. It is found in abundance along the banks of the Usumacinta, and other large rivers flowing into the Gulf of Mexico, as well as in the larger islands of the W. Indies. British settlements for cutting and shipping the timber were established so long ago as 1638–40, and the right to the territory has been maintained by Great Britain, chiefly on account of the importance of this branch of industry. The cutting-season usually commences about August. It is performed by gangs of men, numbering 20–50, under direction of a "captain" and accompanied by a "huntsman," the duty of the latter being to search out suitable trees, and guide the cutters to them. The felled trees of a season are scattered over a very wide area. All the larger ones are "squared" before being brought away on wheeled trucks along the forest-roads made for the purpose. By March–April, felling and trimming are completed; the dry season by that time permits the trucks to be wheeled to the river-banks. A gang of 40 men work 6 trucks, each requiring 7 pair of oxen and 2 drivers. Arrived at the river, the logs, duly initialed, are thrown into the stream; the rainy season follows in May–June, and the rising current carries them seawards, guided by men following in canoes. A boom at the river-mouth stops the timber, and enables each owner to identify his property. They are then made up into rafts, and taken to the wharves, for a final trimming before shipment. The cutters often continue their operations far into the interior, and over the borders into Guatemala and Yucatan.

The exports of mahogany from British Honduras were 1,821,307 ft. in 1876, 3,080,807 in 1877, 3,146,582 in 1878. San Domingo exported in 1880: 18,000 ft. to Great Britain, 62,400 to France, 24,200 to Germany, 58,500 to Italy, 86,650 to Spain, 104,000 to the W. Indies; total, 353,750 ft. The approximate London market values are:—Cuba, 5–9*d.* a ft.; San Domingo, 5–9*d.*; Mexican, 4–5*d.*; Tobasco, 4½–6*d.*; Honduras, 4–5½*d.* (See Mahogany-gum, p. 1673.)

Mahogany [African] (*S. senegalensis*).—This hard and durable wood is brought from Sierra Leone, and is much used for purposes requiring strength, hardness, and durability. But it is very liable to premature decay, if the heart is exposed in felling or trimming.

Mahogany [E. Indian].—Two species of *Swietenia* are indigenous to the E. Indies:—*S. febrifuga* is a very large tree of the mountains of Central Hindostan; the wood is less beautiful than true mahogany, but much harder, heavier, and more durable, being considered the most lasting timber in India. *S. chloroxylon* is found chiefly in the Circar mountains, and attains smaller dimensions; the wood more resembles box.

Mango (*Mangifera indica*).—This tree grows abundantly in India, where numerous varieties are cultivated, as also in Mauritius, Brazil, and in other tropical climates. Its wood is generally coarse and open-grained, but is excellent for common doors and door-posts when well seasoned; it is light and strong, but liable to snap; it is durable in the dry, but decays rapidly when exposed to weather or water, and is much attacked by worms and ants. Its weight is 41 lb. a cub. ft.; cohesive force, 7700 lb.; breaking-weight, 560 lb. (See Resins, p. 1673.)

Maple (*Acer saccharinum*).—The sugar-maple (see pp. 1902–3) is liable to a peculiarity of growth, which gives the wood a knotted structure, whence it is called "bird's-eye maple." The cause of this structure has never been satisfactorily explained. The handsome appearance thus given to the wood is the reason of its value in furniture and cabinet-making.

Miro (*Podocarpus ferruginea*).—This is a New Zealand tree, giving brownish wood 20–30 ft. long and 15–30 in. sq., useful for internal carpentry and joinery, and weighing 46 lb. a cub. ft.

Mora (*Mora excelsa*).—This tree is a native of British Guiana and Trinidad, growing luxuriantly on sand-reefs and barren clays of the coast regions, reaching 130–150 ft. high, and squaring 18–20 in. Its wood is extremely tough, close, and cross-grained, being one of the most difficult to split. It is one of the eight first-class woods at Lloyd's, making admirable keels, timbers, beams, and knees, and in most respects superior to oak. Its weight is 57 lb. a cub. ft.; crushing-force, 10,000 lb., breaking-weight, 1212 lb.

Mutti (*Terminalia coriacea*).—This is a common tree of Central and S. India. Its wood is hard, heavy, tough, fibrous, close-grained, rather difficult to work, unaffected by white ants, and considered extremely durable. It is used for beams and telegraph-posts. Its weight is 60 lb. a cub. ft.; breaking-weight, 860 lb.

Nan-mu (*Persea Nanmu*).—That portion of the Chinese province of Yunnan which lies between 25° and 26° N. lat. produces the famous *nan-mu* tree, which is highly esteemed by the Chinese for building and coffins, on account of its durability and pleasant odour. It is imported into Shanghai in planks measuring 8 ft. long and 13–14 in. diam., for which the highest price is 200 *dol.* (of 4*s.* 2*d.*) a plank.

Naugiia.—This tree is generally found in the Pacific Islands on desert shores, or on the brinks of lagoons, where its roots are bathed by the tide. Its wood has great weight, intense hardness, and closeness of grain. It is considered a valuable substitute for box for wood-engraving (see p. 1610). Blocks 18 in. diam. are common.

Neem (*Melia Azadirachta*).—This is a common, hardy, and quick-growing Indian tree, reaching 40–50 ft. high, and 20–24 in. diam. The trunk and branches are cut into short, thick planks, much used for lintels of doors and windows. The wood is hard and durable, but attacked by insects. Its fragrant odour makes it in request by natives for doors and door-frames. It is difficult to work, takes a fine polish, and is good for joinery where strength is not demanded; but becomes brittle and liable to snap when dry. Its weight is 51 lb. a cub. ft.; cohesive force, 6940 lb.; breaking-weight, 600 lb. (See Oils—Margosa, p. 1395.)

Oak (*Quercus spp.*).—The most common British oak is *Q. pedunculata*, found throughout Europe from Sweden to the Mediterranean, and in N. Africa and Asia. Its wood is tolerably straight and fine in the grain, and generally free from knots. It splits freely, makes good laths for plasterers and slaters, and is esteemed the best kind for joists, rafters, and other purposes where a stiff, straight wood is desirable. The "durmast" oak (*Q. sessiliflora*) has the same range as the preceding, but predominates in the German forests. Its wood is heavier, harder, and more elastic; liable to warp, and difficult to split. Both are equally valuable in ship-building. Quantities of oak timber are shipped from Norway, Holland, and the Baltic ports, but are inferior to English-grown for ship-building, though useful for other purposes.

Of American oaks, the most important are as follows. The chestnut-leaved (*Q. prinos*) gives a coarse-grained wood, very serviceable for wheel-carriages. The red (*Q. rubra*) in Canada and the Alleghanies, affords a light, spongy wood, useful for staves. The wood of the white oak (*Q. alba*), ranging from Canada to Carolina, is tough, pliable, and durable, being the best of the American kinds, but less durable than British. It is exported from Canada to Europe as "American oak." The iron or post oak (*Q. obtusiloba*), found in the forests of Maryland and Virginia, is frequently called the "box white oak," and chiefly used for posts and fencing. The live oak (*Q. virens*) is the best American ship-building kind, inhabiting the Virginian coast.

Oak warps, twists, and shrinks much in drying. Its weight is 37–68 lb. a cub. ft., according to the kind; cohesive force, 7850–17,892 lb. It is valuable for all situations when it is exposed to the weather, and where its warping and flexibility are not objectionable. Quebec oak is worth about 4*l.* 10*s.*–7*l.* a load; Dantzic and Memel, 3*l.* 10*s.*–5*l.* (See Acorn-oil, p. 1415; Cork, pp. 722–9; Valonia, pp. 1992–3; Oak-barks, pp. 1987–8.)

Oak [African], African Teak, or Turtosa (*Oldfieldia africana*).—This important W. African timber has lately been largely imported from Sierra Leone as a substitute for oak and teak. Though stronger than these, its great weight precludes its general use; but it is valuable for certain parts of ships, as beams, keelsons, waterways, and it will stand much heat in the wake of steamer fires, decaying rapidly, however, in confined situations. It warps in planks, swells with wet, and splits in drying again; it is not proof against insects. Its weight is 58–61 lb. a cub. ft.; cohesive force, 17,000–21,000 lb.

Oak [Australian].—Two hard-wooded trees of Australia are the forest-oak (*Casuarina torulosa*) and the forest swamp-oak (*C. paludosa*). They reach 40–60 ft. high and 12–30 in. diam., and are used in house-building, mainly for shingles, as they split almost as neatly as slate. They weigh 50 lb. a cub. ft.; crushing-force, 5500 lb.; breaking-weight, 700 lb.

The she-oak (*C. quadrivalvis*) and he-oak (*C. suberosa*) of Tasmania are used mostly for ornamental purposes.

Pai-ch'ha (*Euonymus sp.*).—The wood of this tree has been alluded to (p. 1610) as a substitute for box-wood, being extensively produced in China, and largely used at Ningpo and other places for wood-carving. It is very white, of fine grain, cuts easily, and is well suited for carved frames, cabinets, &c.; but it is not at all likely to supersede box-wood, though well fitted for coarser work.

Pear (*Pyrus communis*).—Pear-tree wood is one of the heaviest and hardest of the timbers indigenous to Britain. It has a compact fine grain, and takes a high polish; it is in great request by millwrights in France for making wheel-cogs, rollers, cylinders, blocks, &c., and is preferred before all others for the screws of wine-presses. It ranks second to box for wood-engraving and turnery.

Persimmon (*Diospyros virginiana*).—The Virginian date-palm or persimmon is a native of the United States, growing 50–60 ft. high and 1½ ft. diam. Its heart-wood is brown, hard, and elastic, but liable to split; it has been with some success introduced into England as a substitute for boxwood in shuttle-making and wood-engraving.

Pine [Black] or Matai (*Podocarpus spicata*).—This New Zealand timber is much more durable than Miro (p. 2017), and is used for all purposes where strength and solidity are required. Its weight is 40 lb. a cub. ft.; breaking-weight, 420–800 lb.

Pine [Cluster] or Pinaster (*Pinus Pinaster*).—This pine inhabits the rocky mountains of Europe, and is cultivated in English plantations; it reaches 50–60 and even 70 ft. in height. It likes deep dry sand, or sandy loam in a dry bottom; but avoids all calcareous soils. The wood is said to be more durable in water than in air. It is much used in France for shipping-packages, piles and props in ship-building, common carpentry, and fuel. It weighs 25½ lb. a cub. ft.

Pine [Huon] (*Dacrydium Franklinii*).—This tree is said to be abundant in portions of S.-W. Tasmania, growing 50–100 ft. high and 3–8 ft. diam. The wood is clean and fine-grained, being closer and more durable than American White Pine, and can be had in logs 12–20 ft. long and 2 ft. sq. Its weight is 40 lb. a cub. ft.

Pine [Moreton Bay] (*Araucaria Cunninghami*).—This abundant Queensland tree grows over 150 ft. high and 5 ft. diam., giving spars 80–100 ft. long. Its wood is straight-grained, tough, and excellent for joinery; but is not so durable as Yellow Pine, and is liable to attacks of sea-worms and white ants. It is used for flooring and general carpentry, and for shingles; it holds nails and screws well. Its weight is 45 lb. a cub. ft.

Pine [Norfolk Island] (*A. excelsa*).—This tree inhabits Norfolk Island and Australia, growing 200–250 ft. high and 10–12 ft. diam. Its wood is tough, close-grained, and very durable for indoor work.

Pine [Northern], or Red, Yellow, Scotch, Memel, Riga, or Dantzic Fir (*Pinus sylvestris*).—This tree forms with the spruce fir the great forests of Scandinavia and Russia, and attains considerable size in the highlands of Scotland. The logs shipped from Stettin reach 18–20 in. sq.; those from Dantzic, 14–16 in. and even 21 in. sq., and up to 40–60 ft. long; from Memel, up to 13 in. sq., and 35 ft. long; from Riga, 12 in. sq. and 40 ft. long, and spars 18–25 in. diam. and 70–80 ft. long; Swedish and Norwegian, up to 12 in. sq. It comes also in planks (11 in. wide), deals (9 in.), and battens (7 in.). The best are Christiania yellow deals, but contain much sap; Stockholm and Gefle are more disposed to warp; Gottenburg are strong, but bad for joinery; Archangel and Onega are good for joinery, but not durable in damp; Wiborg are the best Russian, but inclined to sap; Petersburg and Narva yellow are inferior to Archangel. Well-seasoned pine is almost as durable as oak. Its lightness and stiffness render it the best timber for beams, girders, joists, rafters, and framing; it is much used for masts; and for joinery is superior to oak on all scores. The hardest comes from the coldest districts. The cohesive force is 7000–14,000 lb. per sq. in.; weight, 29–40 lb. per cub. ft.; strength, 80; stiffness, 114; toughness, 56. (See Rosin, p. 1680; Pitch, pp. 1678–9; Pine-oils, p. 1408; Turpentine-oils, p. 1431; Thus, p. 1684; Tars, p. 1683; Turpentine, p. 1687.)

Pine [Pitch] (*P. rigida* [*resinosa*]).—This species is found throughout Canada and the United States, most abundantly along the Atlantic coast. The wood is heavy, close-grained, elastic, and durable, but very brittle when old or dry, and difficult to plane. The heart-wood is good against alternate damp and dryness, but inferior to White Pine underground. Its weight is 41 lb. per cub. ft.; cohesive force, 9796 lb. per sq. in.; stiffness, 73; strength, 82; toughness, 92.

Pine [Red, Norway, or Yellow] (*P. rubra* [*resinosa*]).—This tree grows on dry stony soils in Canada, Nova Scotia, and the N. United States, reaching 60–70 ft. high, and 15–25 in. diam. at 5 ft. above ground. The wood weighs 37 lb. per cub. ft.; it is much esteemed in Canada for strength and durability, and, though inferior in these respects to Northern Pine, is preferred by English shipwrights for planks and spars, being soft, pliant, and easily worked.

Pine [Red] or Rimu (*Dacrydium cupressinum*).—This New Zealand wood runs 45 ft. long, and up to 30 in. sq., and is much used in house-framing and carpentry, but is not so well adapted to joinery, as it shrinks irregularly. It weighs 40 lb. a cub. ft. (See Rimu-resin, p. 1680.)

Pine [Weymouth or White] (*Pinus strobus*).—This tree inhabits the American continent between 43° and 47° N. lat., occupying almost all soils. The timber is exported in logs over 3 ft. sq. and 30 ft. long; it makes excellent masts; is light, soft, free from knots, easily worked, glues well, and is very durable in dry climates; but is unfit for large timbers, liable to dry-rot, and not durable in damp places, nor does it hold nails well. It is largely employed for wooden houses and timber bridges in America. Its weight is 28¾ lb. per cub. ft.; cohesive force, 11,835 lb.; stiffness, 95; strength, 99; toughness, 103.

Pine [White], or Kahikatea (*Podocarpus dacrydioides*).—This New Zealand timber tree gives wood 40 ft. long and 24–40 in. sq., straight-grained, soft, flexible, warping and shrinking little, and well adapted for flooring and general joinery, though decaying rapidly in damp. Its weight is 30 lb. a cub. ft.; breaking-weight, 620 lb.

Pine [Yellow, Spruce, or Short-leaved] (*Pinus variabilis* and *P. mitis*).—The former species is found from New England to Georgia, the wood being much used for all carpentry, and esteemed for large masts and yards; it is shipped to England from Quebec. The latter is abundant in the Middle States and throughout N. America, reaching 50–60 ft. high and 18 in. diam. It is much used locally for framework: the heart-wood is strong and durable; the sap-wood is very inferior.

Plane (*Platanus orientalis* and *P. occidentalis*).—The first species inhabits the Levant and adjoining countries, growing 60–80 ft. high and up to 8 ft. diam. The wood is more figured than beech, and is used in England for furniture; in Persia, it is applied to carpentry in general.

The second species, sometimes called "water-beech," "button-wood," and "sycamore," is one of the largest N. American trees, reaching 12 ft. diam. on the Ohio and Mississippi, but generally 3–4 ft. The wood is harder than the oriental kind, handsome when cut, works easily, and stands fairly well, but is short-grained and easily broken. It is very durable in water, and preferred in America for quays. Its weight is 40–46 lb. a cub. ft.; cohesive force, 11,000 lb.; strength, 92; stiffness, 78; toughness, 108.

Poon (*Calophyllum Burmanni*).—This tree is abundant in Burma, S. India, and the E. Archipelago. It is tall and straight, and about 6 ft. circ. It is used for the decks, masts, and yards of ships, being strong and light. Its texture is coarse and porous, but uniform: it is easy to saw and work up, holds nails well, but is not durable in damp. Its weight is 40–55 lb. a cub. ft.; cohesive force, 8000-14,700 lb. Another species (*C. angustifolium*) from the Malabar Hills is said to furnish spars.

Poplar (*Populus spp.*).—Five species of poplar are common in England: the white (*P. alba*), the black (*P. nigra*), the grey (*P. canescens*), the aspen or trembling poplar (*P. tremula*), and the Lombardy (*P. dilatata*); and two in America: the Ontario (*P. macrophylla*), and the black Italian (*P. acladesca*). They grow rapidly, and their wood is generally soft and light, proving durable in the dry, and not liable to swell or shrink. It makes good flooring for places subject to little wear, and is slow to burn. It is much used for butchers' trays and other purposes where weight is objectionable. The Lombardy is the lightest and least esteemed, but is proof against mice and insects. The weight is 24–33 lb. a cub. ft.; cohesive force, 4596–6641 lb.; strength, 50–86; stiffness, 44–66; toughness, 57–112. Poplar is one of the best woods for paper-making (see p. 1493). The trees also yield an oil (p. 1427).

Pymma (*Lagerstrœmia reginæ*).—The wood of this abundant Indian tree, particularly in S. India, Burma, and Assam, is used more than any except teak, especially in boat-building, and posts, beams, and planks in house-building. Its weight is 40 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; breaking-weight, 640 lb.

Pynkado or Ironwood (*Inga xylocarpa*).—This valuable timber tree is found throughout S. India and Burma. Its wood is hard, close-grained, and durable; but it is heavy, not easily worked, and hard to drive nails into. It is much used in bridge-building, posts, piles, and sleepers. Its weight is 58 lb. a cub. ft.; cohesive force, 16,000 lb.; breaking-weight, 800 lb.

Rata (*Metrosideros lucida*).—This tree is indigenous to New Zealand, giving a hard timber 20–25 ft. long and 12–30 in. sq., very dense and solid, weighing 65 lb. a cub. ft.

Rohun (*Soymida febrifuga*).—This large forest tree of Central and S. India affords a close-grained, strong and durable wood, which stands well when underground or buried in masonry, but not so well when exposed to weather. It is useful for palisades, sleepers, and house-work, and is not very difficult to work. Its weight is 66 lb. a cub. ft.; cohesive force, 15,000 lb.; breaking-weight, 1000 lb.

Rosewood.—The term "rosewood" is applied to the timber of a number of trees, but the most important is the Brazilian. This is derived mainly it would seem from *Dalbergia nigra*, though it appears equally probable that several species of *Triptolemæa* and *Machærium* contribute to the inferior grades imported thence. The wood is valued for cabinet-making purposes. The approximate London market values are 12–25*l.* a ton for Rio, and 10–22*l.* for Bahia.

Sabicu (*Lysiloma Sabicu*).—This tree is indigenous to Cuba, and found growing in the Bahamas, where it has probably been introduced. Its wood is exceedingly hard and durable, and has been much valued for ship-building. It has been imported from the Bahamas in uncertain quantities for the manufacture of shuttles and bobbins for cotton-mills. The exports thence were 167 tons in 1878, and 101 tons in 1879.

Sal or Saul (*Shorea robusta*).—This noble tree is found chiefly along the foot of the Himálayas, and on the Vindhyan Hills near Gaya, the best being obtained from Morung. Its wood is strong, durable, and coarse-grained, with particularly straight and even fibre; it dries very slowly, continuing to shrink years after other woods are dry. It is used chiefly for floor-beams, planks, and roof-trusses, and can be had in lengths of 30–40 ft., and 12–24 in. sq. Its weight is 55–61 lb. a cub. ft.; cohesive force, 11,500 lb.; crushing-force, 8500 lb.; breaking-weight, 881 lb.

Satin-wood.—The satin-wood of the Bahamas is supposed to be the timber of *Maba guianensis*, an almost unknown tree. The Indian kind is derived from *Chloroxylon Swietenia*, a native of Ceylon, the Coromandel coast, and other parts of India. The former comes in square logs or planks 9–20 in. wide; the latter, in circular logs 9–30 in. diam. The chief use of satin-wood is for making the backs of hair- and clothes-brushes, turnery, and veneering. The exports from the Bahamas were 5037 pieces in 1878, and 18,783 in 1879, all to England. The approximate value of San Domingan is 6–18*d.* a ft. The Indian tree yields a gum (see p. 1682).

Sissu or Seesum (*Dalbergia Sissu*).—This tree is met with in many parts of India, being said to attain its greatest size at Chanda. Its wood resembles the finest teak, but is tougher and more elastic. Being usually crooked, it is unsuited for beams, though much used by Bengal ship-builders, and in India generally for joinery and furniture. Its weight is 46½ lb. a cub. ft.; cohesive force, 12,000 lb.; breaking-weight, 700 lb.

Sneezewood or Nies Hout (*Pteroxylon utile*).—This most durable S. African timber, the *oomtata* of the natives, is invaluable for railway-sleepers and piles, being almost imperishable.

Spruce Fir [American Black] (*Abies nigra*).—This tree inhabits Canada and the N. States, being most abundant in cold-bottomed lands in Lower Canada. It reaches 60–70 and even 100 ft. high, but seldom exceeds 24 in. diam. The wood is much used in America for ships' knees, when oak and larch are not obtainable.

Spruce Fir [American White], Epinette, or Sapinette blanche (*A. alba*).—This white-barked fir is a native of high mountainous tracts in the colder parts of N. America, where it grows 40–50 ft. high. The wood is tougher, lighter, less durable, and more liable to twist in drying than white deal, but is occasionally imported in planks and deals. It weighs 29 lb. a cub. ft.; cohesive force, 8000 to 10,000 lb.; strength, 86; stiffness, 72; toughness, 102.

Spruce Fir [Red], or Newfoundland Red Pine (*A. rubra*) —This species grows in Nova Scotia, and about Hudson's Bay, reaching 70–80 ft. high. It is universally preferred in America for ships' yards, and imported into England for the same purpose. It unites in a higher degree all the good qualities of the Black Spruce Fir.

Stringy-bark (*Eucalyptus gigantea*).—This tree affords one of the best building woods of Australia, being cleaner and straighter-grained than most of the other species of *Eucalyptus*. It is hard, heavy, strong, close-grained, and works up well for planking, beams, joists, and flooring, but becomes more difficult to work after it dries, and shrinks considerably in drying. The outer wood is better than the heart. Its weight is 56 lb. a cub. ft.; crushing-force, 6700 lb.; breaking-weight, under 500 lb.

Sycamore or Great Maple (*Acer pseudo-platanus*). — This tree, mis-called "plane" in N. England, is indigenous to mountainous Germany, and very common in England. It thrives well near the sea, is of quick growth, and has a trunk averaging 32 ft. long and 29 in. diam. The wood is durable in the dry, but liable to worms; it is chiefly used for furniture and ornaments. Its weight is 34–42 lb. a cub. ft.; cohesive force, 5000–10,000 lb.; strength, 81; stiffness, 59; toughness, 111.

Tamanu (*Calophyllum sp.*).—This valuable tree of the S. Sea Islands is becoming scarce. It sometimes reaches 200 ft. high and 20 ft. diam. Its timber is very useful for ship-building and ornamental purposes, and is like the best Spanish mahogany. It yields an oil (see Dilo, p. 1387), and a resin (see Tamanu, p. 1683).

Tanakaha (*Podocarpus asplenifolius*).—This is a light-coloured New Zealand wood, close and straight in the grain, and running 20–40 ft. long and 10–16 in. sq.

Teak (*Tectona grandis*).—This tall, straight, rapidly-growing tree inhabits the dry elevated districts of the Malabar and Coromandel coasts of India, as well as Burma, Pegu, Java, and Ceylon. Its wood is light, easily worked, strong, and durable; it is the best for carpentry where strength and durability are required, and is considered foremost for ship-building. The Moulmein product is much superior to the Malabar, being lighter, more flexible, and freer from knots. The Vindhyan excels that of Pegu in strength, and in beauty for cabinet-making. The Johore is the heaviest and strongest, and is well suited for sleepers, beams, and piles. It is unrivalled for resisting worms and ants. Its weight is 45–62 lb. a cub. ft.; cohesive force, 13,000–15,000 lb.; strength, 109; stiffness, 126; toughness, 94. The quantities of teak brought down from British Burma were 46,431 tons in 1876–7, 39,081 in 1877–8, 22,763 in 1878–9, 17,585 in 1879–80. The approximate market value is 8–15*l.* a load. (See Tar, p. 1684.)

Toon, or Chittagong wood (*Cedrela Toona*).—This tree is a native of Bengal and other parts of India, where it is highly esteemed for joinery and furniture, measuring sometimes 4 ft. diam., and somewhat resembling mahogany. Its weight is 35 lb. a cub. ft.; cohesive force, 4992 lb.; breaking-weight, 560 lb.

Totara (*Podocarpus Totara*).—This tree is fairly abundant in the N. and S. islands of New Zealand, reaching 80 ft. high and 2½–3½ ft. diam. Its wood is easily worked, straight- and even-grained, warps little, and splits very clean and free; but it is brittle, apt to shrink if not well seasoned, and subject to decay in the heart. It is used generally for joinery and house-building. Its weight is 40 lb.; breaking-weight, 570 lb.

Walnut (*Juglans regia*).—The walnut-tree is a native of Greece, Asia Minor, Persia, along the Hindu Kush to the Himálayas, Kashmir, Kumaon, Nepal, and China, and is cultivated in Europe up to 55° N. lat., thriving best in dry, deep, strong loam. It reaches 60 ft. high and 30–40 in. diam. The young wood is inferior; it is in best condition at about 50–60 years. Its scarcity excludes it from building application, but its beauty, durability, toughness, and other good qualities render it esteemed for cabinet-making and gun-stocks. Its weight is 40–48 lb. a cub. ft.; cohesive force, 5360–8130 lb.; strength, 74; stiffness, 49; toughness, 111; all taken on a green sample.

Of the walnut-burrs (or *loupes*), for which the Caucasus was once famous, 90 per cent. now come from Persia. The walnut forests along the Black Sea, which give excellent material for gun-stocks, do not produce burrs, which occur only in the drier climates of Georgia, Daghestan, and Persia. Italian walnut is worth 4–5½*d.* a ft. Poti exported 35,413 *poods* (of 36 lb.) in 1877–8. Trebizonde, in 1879, sent 32 cwt. to Turkey, 2765 to Great Britain, 12,179 to France; total value, 29,956*l.*; in 1880, 1832 cwt. to Great Britain, and 4137 to France; total value, 11,938*l.* Samsoun exported 1000 cwt., 2000*l.*, in 1880. Ancona exported 131,209 planks, value 37,895*l.*, to Great Britain in 1878. (See Nuts, p. 1360; Oils, p. 1413.)

Walnut [Black Virginia] (*J. nigra*).—This is a large tree ranging from Pennsylvania to Florida; the wood is heavier, stronger, and more durable than European walnut, and is well adapted for naval purposes, being free from worm attacks in warm latitudes. It is extensively used in America for various purposes, especially cabinet-making.

Willow (*Salix spp.*).—The wood of the willow is soft, smooth, and light, and adapted to many purposes. It is extensively used for the blades of cricket-bats, for building fast-sailing sloops, and in hat-making (see pp. 1102–27), and its charcoal is used in gunpowder-making (see p. 882).

Yellow-wood or Geel Hout (*Taxus elongatus*).—This is one of the largest trees of the Cape Colony, reaching 6 ft. diam. Its wood is extensively used in building, though it warps much in seasoning, and will not bear exposure.

Yew (*T. baccata*).—This long-lived shrubby tree inhabits Europe, N. America, and Japan, being found in most parts of Europe at 1000–4000 ft., and frequently on the Apennines, Alps, and Pyrenees, and in Greece, Spain, and Great Britain. The stem is short, but reaches a great diameter (up to 20 ft.). The wood is exceedingly durable in flood-gates, and beautiful for cabinet-making. Its weight is 41–42 lb. a cub. ft.; cohesive force, 8000 lb.

Commerce.—Our imports of wood and timber in 1880 were as follows:—Hewn Fir: From Norway, 338,943 loads, 506,142*l.*; Russia, 331,012 loads, 630,894*l.*; Sweden, 308,702 loads, 527,163*l.*; France, 293,117 loads, 295,805*l.*; British N. America, 262,663 loads, 1,012,210*l.*; Germany, 225,964 loads, 520,949*l.*; United States, 137,017 loads, 440,262*l.*; other countries, 13,191 loads, 13,055*l.*; total, 1,910,609 loads, 3,946,480*l.*

Hewn Oak: From Germany, 46,276 loads, 225,234*l.*; British N. America, 44,888 loads, 277,945*l.*; Russia, 3285 loads, 35,160*l.*; United States, 1725 loads, 12,672*l.*; France, 1206 loads, 5554*l.*; Austria, 959 loads, 8657*l.*; other countries, 160 loads, 1896*l.*; total, 98,499 loads, 567,118*l.*

Hewn Teak: From Bengal and Burma, 33,211 loads, 401,361*l.*; other countries, 652 loads, 9073*l.*; total, 33,863 loads, 410,434*l.*

Hewn, unenumerated: From British N. America, 65,512 loads, 249,180*l.*; Norway, 5576 loads, 10,108*l.*; British Guiana, 4938 loads, 37,289*l.*; Sweden, 4675 loads, 8103*l.*; other countries, 6869 loads, 23,437*l.*; total, 87,570 loads, 328,117*l.*

Sawn or Split, Planed or Dressed Fir: From British N. America, 1,158,653 loads, 3,037,481*l.*; Sweden, 1,066,394 loads, 2,833,692*l.*; Russia, 966,513 loads, 2,508,514*l.*; Norway, 366,400 loads, 1,002,885*l.*; United States, 171,049 loads, 522,591*l.*; Germany, 63,973 loads, 165,876*l.*; other countries, 2860 loads, 4217*l.*; total, 3,795,842 loads, 10,075,256*l.*

Ditto, unenumerated: From Sweden, 138,619 loads, 176,481*l.*; Russia, 95,505 loads, 145,364*l.*; Norway, 38,760 loads, 46,626*l.*; Holland, 15,866 loads, 75,079*l.*; British N. America, 14,367 loads, 44,504*l.*; United States, 10,626 loads, 61,618*l.*; Germany, 5367 loads, 14,270*l.*; other countries, 1797 loads, 6750*l.*; total, 320,907 loads, 570,692*l.*

Staves: From Norway, 30,283 loads, 75,871*l.*; Germany, 21,344 loads, 178,461*l.*; Russia, 16,592 loads, 43,752*l.*; Sweden, 15,670 loads, 36,476*l.*; United States, 11,590 loads, 75,040*l.*; British N. America, 6493 loads, 42,041*l.*; Austria, 1545 loads, 18,056*l.*; other countries, 19 loads, 150*l.*; total, 103,536 loads, 469,847*l.*

Furniture hardwoods and veneers: Mahogany: From Mexico, 24,096 tons, 218,604*l.*; British Honduras, 6132 tons, 41,310*l.*; Spanish W. Indies, 5099 tons, 44,748*l.*; Central America, 3295 tons, 28,384*l.*; Hayti and San Domingo, 1290 tons, 13,613*l.*; other countries, 1437 tons, 12,206*l.*; total, 41,349 tons, 358,865*l.*

Ditto, unenumerated: From United States, 11,389 tons, 96,607*l.*; British N. America, 4328 tons, 33,046*l.*; British W. Indies, 2898 tons, 22,734*l.*; Turkey, 2712 tons, 34,689*l.*; France, 2294 tons, 47,296*l.*; Spanish W. Indies, 2288 tons, 19,929*l.*; Italy, 1769 tons, 12,054*l.*; W. Africa, 1733 tons, 14,872*l.*; Germany, 1219 tons, 11,849*l.*; Australia, 1194 tons, 9652*l.*; Brazil, 1135 tons, 16,979*l.*; Central America, 1107 tons, 8464*l.*; other countries, 3780 tons, 36,543*l.*; total, 37,846 tons, 364,714*l.*

Bibliography.—R. Fowke, 'Strengths of British, Colonial, and other Woods' (Lond.: 1867); C. Walker, 'Rep. on Forest Management' (Lond.: 1873); C. F. Amery, 'Notes on Forestry' (Lond.: 1875); T. Laslett, 'Timber and Timber Trees' (Lond.: 1875); A. E. Dupont and A. Bouquet de la Grye, 'Les Bois indigènes et étrangers' (Paris: 1875); M. M'Turk, 'The Woods of British Guiana' (1878); A. T. Drummond, 'Canadian Timber Trees' (Montreal: 1879); W. H. Ablett, 'English Trees and Tree-planting' (Lond.: 1880); J. T. Hurst, 'Tredgold's Carpentry' (Lond.: 1880); A. Des Cars, 'Tree-pruning' (Boston: 1881); H. Sebert, 'Les Bois de la Nouvelle Calédonie' (Paris: n. d.); H. M. Hull, 'Tasmania and its Timber,' and J. E. Calder, 'The Forests of Tasmania' (Proc. R. Col. Inst., Lond.: 1873, 1874).

VARNISH (Fr., *Vernis*; Ger., *Firniss*).

A "varnish" is any substance which, when applied to the surface of an object, leaves on that surface a continuous, smooth, impervious coating, whose functions are:—(1) To increase the lustre and polish of that surface, and, by obliterating its asperities and filling up its pores, prevent its easy soiling, and facilitate washing (e. g. paint, *papier-maché*, glazing of pottery, &c.); (2) by its high refractive power to increase the transparency of surfaces which are by their porosity rendered too opaque, and thus to bring into view any "grain" or interior structure which it is desirable to show up (e. g. oiling, varnishing, or waxing wood, transparent blinds, tracing-paper, &c.); (3) by its insolubility in water and oils, to protect perishable structures from the effect of damp, decay, mould, &c., metals from rust and corrosion by acids, and porous bodies from grease-spots; (4) by hardening the surface of softer objects to save them from abrasion (e. g. varnishing deal and other soft woods, pasteboard, book-covers, leather, &c.).

Varnishes group themselves naturally into 5 well-marked divisions:—I. Natural lacquers of the Indian and Chinese type, produced by several genera of trees of the natural order *Anacardiaceæ*. These are liquid at first, but dry slowly (by oxidation?) on exposure to the air (see p. 1692). II. Drying oils, which indurate or resinify by oxidation in the air, either in their natural state, or made more drying by various chemical treatment. III. Oil-varnishes proper, composed of an intimate combination of a drying oil with a fused resin, and hardening by the oxidation of the oil. These may either be applied in their undiluted state, or may be thinned with essential oils, or other liquid volatile hydrocarbons, to such a consistence as will enable them to be applied with a brush. IV. Varnishes composed of a volatile liquid holding in solution resins, or gums, or other solid amorphous (non-crystalline) substances, which, on the evaporation of the solvent, are left behind as a vitreous coating on the surface varnished. V. Glazes and enamels, applied to the work in a solid state, in powder or otherwise, and attached to its surface by raising it to a heat sufficient to melt the glaze, &c.; or formed by the fused surface of the object itself, when vitrified at a high temperature by appropriate fluxes (e. g. etching-ground, glazing of porcelain and pottery, salt-glazed stoneware, &c., the last two not coming within the scope of this article, but described on pp. 1571–2, 1594–6).

Materials used in Varnish-making.—These may be conveniently arranged under 6 separate heads, according to the part they play in the finished varnish:—(1) The drying oils. (2) Those resins which have sufficient hardness and transparency for the purpose, and whose melting-point is high enough to prevent their becoming softened and sticky in summer, in heated rooms, or by the heat of the hand. (3) "Colloid" bodies soluble in water, such as albumen, gum arabic, dextrine, gelatine, &c. (4) "Solvents," i. e. volatile liquids used to dissolve resins or gums, or to dilute oil-varnishes, but which evaporate entirely during the drying of the varnish, thus contributing nothing to the thickness of the coating. (5) "Tougheners," or substances added to varnishes, of Class IV., to make them more flexible, and less liable to crack, or be scratched. (6) "Driers," which, by giving up oxygen, or by acting as "carriers" of atmospheric oxygen, hasten the hardening of the drying oils. (7) Soluble transparent colouring matters, resinous or otherwise, used in lacquers and changing-varnishes.

Drying-oils.—The principal oils in use at the present day for paints and varnishes are those of the poppy, walnut, hemp-seed, and linseed.

Poppy-oil (p. 1403).—The chief use of this oil in England seems to be for the grinding of the fine colours used by artists in picture-painting. Being generally considered (and probably correctly so) a much slower drier than either linseed- or walnut-oil (commonly called "nut-oil"), it is seldom if ever used in varnish-making.

Walnut-oil or Nut-oil (p. 1413).—With regard to the drying powers of this oil, some authorities place it above linseed-oil, and others below it, whilst most of the older writers considered it as very little, if at all, inferior. We are inclined, from all accounts, to agree with the last-mentioned opinion, although almost all that comes into the English market is far inferior to linseed-oil. The cause may be that the palest oil has been chosen in the Continental market as the best as well as the dearest, but in ignorance of the fact that the best salad oils are generally the worst driers.

Hempseed-oil (p. 1391).—This is generally supposed to be about equal to linseed- and walnut-oils in drying quality. It is said to make a very bad-smelling and deep-coloured boiled oil; but seems, from all accounts, to be much used in E. and N. Europe for paints and varnishes, though very little, if at all, in England.

Linseed-oil (p. 1393).—This oil, which from its high drying property, its cheapness, its steady supply, and its great constancy of quality (when free from any adulteration with non-drying oils), is universally employed in W. Europe for oil-varnishes, and boiled oil for painting, japanning, floor-cloth, and all other purposes where a strongly-drying oil is required; it is also the one prescribed in the oldest of all known recipes for varnish and for oil-painting.

All oil to be used in oil-varnishes or for boiled oil should be chosen as new, sweet, and free from rancidity as possible, and should be at once clarified and allowed to settle for a few months before being used, so as to deposit impurities, "mucosities," and the substances (if any) used in clarifying it, and, when clear, should be decanted from the dregs, and stored for use in slate or galvanized-iron tanks.

Many methods have been used for the clarification of oils (see p. 1459), to rid them of the gummy and mucous matters, water, saline substances, &c., derived from the seed during expression, and which, besides making the oil turbid, induce a kind of rancid fermentation, and much impair the keeping quality of the oil, and hinder its drying. The simplest of all these processes consists in heating the oil slowly up to 300° (572° F.) either alone or with the addition of 1–5 parts in 1000 of either caustic lime, carbonate of lime, calcined magnesia, or carbonate of magnesia, and keeping it at that temperature for one or two hours, and then allowing it to cool uncovered and undisturbed. The oil should then be transferred to a settling-tank to deposit and clarify.

When thus freed from the impurities arising from the seed, the oil will not so easily get rancid, and will improve by keeping, becoming more pale, limpid, transparent, and drying, in proportion to its age. All oils prescribed in the recipes for oil-varnishes in the course of this article will be supposed to have been clarified by this or some other process.

Resins.—In addition to what has been said under this head (pp. 1621–95), the following may be enumerated with especial reference to their use in varnishes.

Oil-varnish Resins.—(1) Amber (p. 1628) is the hardest and most difficult to fuse, but gives the most durable and resisting oil-varnish, of dark colour unfortunately. (2) The true copals (p. 1640) make the finest of all the oil-varnishes, nearly as hard and durable as amber-varnish, and much paler in colour and more quick-drying. (3) The pseudo-copals,—kauri (p. 1666), and hard and soft Manilla (p. 1678), give varnish inferior to the true copals, but more easily made. (4) Sandarach (p. 1681), is almost unknown as an oil-varnish resin at the present day, its use being entirely confined to spirit-varnishes; it is, however, equal to most of the true copals for varnish-making in point of hardness and general qualities, excepting colour. (5) The resins of the conifers, constituting the "rosin" of commerce (p. 1680), make poor weak varnishes, only fit for the commonest purposes.

All the above oil-varnish resins, with the exception of group 5, are quite insoluble in linseed-oil, turps, and other essential oils, benzol and its homologues, petroleum, chloroform, &c., until they have undergone destructive fusion at nearly red-heat, after which they dissolve freely in all.

Essence-varnish resins.—(1) All the copals, amber, sandarach, and the pseudo-copals, after fusion. (2) All the dammars (p. 1644), without previous fusion. (3) Mastic and other resins from species of *Pistacia* (pp. 1673, 1687). (4) Coniferous resins and turpentines. (5) The resins of copaiba and gurjun balsams (pp. 1639, 1651). These resins are soluble in essential oils and other hydrocarbons, and in ether, chloroform, &c., forming Classes A and B of Div. IV., called oleo-resinous or essential-oil varnishes, and ether varnishes.

Spirit-varnish resins.—(1) Lac (p. 1668), which stands at the head of varnish-making resins, having no rival amongst them for hardness and toughness. (2) Certain true copals from Africa are entirely soluble in strong alcohol (methylated spirit). (3) Soft Manilla copal (so called). (4) Sandarach, which has for several hundred years been the stock resin for pale spirit-varnishes, being the only pale dry resin then known soluble in spirit. (5) The turpentines, rosins, and naturally-dried turpentines ("thus") of nearly all the pines, firs, and larches. (6) The *Pistacia* resins.

Many of the copals and other resins, which are not entirely soluble in strong alcohol, dissolve completely in a mixture of methylated spirit with some simple hydrocarbon, e.g. benzol, toluol, turps, lavender-oil, &c., or with chloroform, acetic ether, or acetone, making excellent varnishes.

To the above resins, may be added a few others, which are only chosen for their colour in lacquers and "changing-varnishes," or to give a more pleasant odour to furniture and fancy varnishes. They are :—

Gamboge (pp. 1551, 1650–1), a bright-yellow gum-resin, yielding its colour to alcohol, turps, ether, benzol, &c., gives the brightest of all yellows for pale brass lacquers.

Dragon's-blood (p. 1648), yields a rich orange-red coloured resin to alcohol, ether, chloroform, and benzol, but not to turps nor petroleum.

Gum Acaroides and Black-boy gum (p. 1693) in solution vary in colour from brownish-yellow to brownish-red. They are insoluble in chloroform, benzol, turps, and petroleum. . They furnish resins hard enough to be used alone as spirit lacquers, for deep brass or bronze.

Aloes (p. 791–3). The inspissated juice of various species of *Aloë* was much used in the 17th and previous centuries, for colouring oil-lacquers and changing-varnishes, used over tinfoil to imitate gilding in decoration, and is still used in pale brass spirit-lacquers.

Benzoin (p. 1637). That which is of the greyest colour, and containing most and largest white tears, will usually give the palest solution in spirit. It is sometimes used alone as a last coat or "finish" to French-polish and other spirit-varnishes, to give scent and brilliancy. It is soluble in all the solvents commonly used, excepting benzol and petroleum, which only dissolve a portion of it.

Asphaltum is of such very important use in all black oil-varnishes and japans, as also in etching-grounds and some black essence-varnishes, and is so liable to adulteration, that great care is requisite in choosing it of good quality. It should be entirely (excepting perhaps 4–5 per cent. of earthy impurities) soluble in chloroform, toluol and its higher homologues, rosin-spirit, and turps, and quite insoluble in alcohol, and in a mixture of equal parts of alcohol and chloroform. It should break with a conchoidal fracture and brilliant resinous lustre ; the rubbed surfaces and angles are usually covered with a bright-brown powder. It should not flow like wood-pitch when laid by for some time on a horizontal surface, and an angular fragment or thin chip should retain its shape and the sharpness of its angles in boiling water, and only begin to flow at a temperature of 150°–200° (300°–400° F.). When adulterated with coal-pitch, it is much less brilliant on the surface of fracture, which then has a lustre rather adamantine or sub-metallic than resinous, and when fused, has a granular, pasty appearance and feel, instead of being smooth and homogeneous, and will not draw out into even and transparent brown threads like pure asphaltum. This is the most important adulteration, a small percentage of coal-pitch spoiling it utterly for varnish-making, or etching-grounds. (See Asphalt, p. 341.)

Gums, &c., used in water-varnishes and glazes.—(1) Gelatine (pp. 522–4, 620–2). That used for glazing paper and fancy articles of cardboard, light wood, &c., should be of the best quality, particularly in damp climates. It should especially be free from saline impurities, and overboiled portions, which make it liable to get damp and sticky in wet weather, besides diminishing its lustre. Parchment-size (p. 622) is one of the best. Of commercial glues and gelatines, those should be chosen which give the stiffest jelly with the same proportion of water.

(2) Gluten of cereals, especially wheat (see pp. 622–3, 1821–9), after washing away the starch, has been used as a varnish when dissolved in weak alcohol, in which a considerable portion is said to be soluble.

(3) Albumen, Caseine, Legumine, &c.—The first two are regularly manufactured as articles of commerce (see pp. 191–2, 1304). Egg-albumen is the cleanest and palest, but requires long-continued "whipping" to thoroughly break down its organized structure, before its glairy character is removed, and the albumen is fit for varnishes. Blood albumen is now manufactured of such excellent quality as to supersede that from eggs wherever large quantities are wanted.

Caseine is also made on a commercial scale, and seems to be used in some of the foreign boot and leather varnishes. Legumine, which might easily be obtained in large quantities from any cheap beans, tares, or other leguminous seeds, has never been used to any important extent in water-varnishes.

(4) Gum arabic and the allied acacia gums (p. 1630) are not so much used pure in glazes and varnishes as gelatine, but enter into and give gloss to many liquid preparations, such as blacking, ink, boot-glosses and varnishes, kid-revivers, &c., and form the vehicle or cementing material for artists' water-colours.

5. Lac, dissolved in water by means of borax or alkaline carbonates, also makes a good water-varnish, and the solution forms the principal ingredient in many of the best boot- and leather-varnishes, and in waterproof inks.

Volatile solvents.—Turps (essential oil or spirit of turpentine,* pp. 1431, 1686) is the volatile oil, obtained by distillation from the turpentines of the coniferous trees, of which it constitutes 10–35 per cent. It is at the present day found very pure in commerce, being at a low price; but when the price becomes high, adulteration with petroleum and rosin-spirit is much practised.

---

* The word "turpentine" has been of late years very generally but most erroneously used to signify the *essential oil* or *spirit* of turpentine, as well as the turpentine itself. It will never be so used in this article, but will be strictly confined to its real meaning, i.e. the natural oleo-resin, as produced by the various coniferous trees, and *Pistacia terebinthus*. The *spirit* of turpentine will be designated by the word "turps", which is in general use, has only one meaning, and has the advantage of brevity.

Turps is the most important solvent used in varnishes of the third and fourth divisions, and every care should be taken to choose it of the best quality, i. e. free from adulteration, and new, or freshly-distilled. Old turps should never be used, especially if it shows the least thickening or "fatness," for although such "fat" turps unquestionably helps oil-varnishes to dry quickly (owing to the oxygen it has absorbed from the air, and holds in very loose combination), and is therefore, and for the brilliancy it gives them, sometimes preferred by varnish-makers of the old school, yet it only does so at great cost of hardness and durability.

Turps is also the solvent chiefly used in varnishes belonging to Class A of the fourth division, and here it is especially desirable that it should be new, or the varnish may remain for days before it is dry enough to be touched with safety, catching dust all the time.

Petroleum, Benzoline, Benzine-spirit, Gazoline, &c. (pp. 1433, 1509). The different substances composing the liquid called "naphtha," vary in composition (and in sp. gr. and boiling-point) from marsh-gas, the first of the series (CH_4) up to the solid paraffins. The oils boiling below 180° (356° F.) may as solvents be conveniently divided into four portions:—(1) Those boiling below 70° (158° F.), (2) between 70° and 100° (158°–212° F.), (3) between 100° and 130° (212°–266° F.), and (4) between 130° and 160° (266°–320° F.). No. 1 may be sometimes used with advantage to replace ether and benzol economically, in varnishes belonging to Class B of Div. IV. intended to dry instantly; No. 2 may replace in Classes B, C, and D, of Div. IV., alcohol in some cases, and benzol and toluol in others; No. 3 evaporates much more quickly than turps, though not so quickly as alcohol, and may therefore be used where an essence-varnish is required to dry rather quickly, or to increase the solvent power of alcohol; and No. 4 is in many cases in Class D of Div. IV. an important substitute for turps, when it is particularly desirable to prepare an oil- or essence-varnish absolutely free from contamination by the resins always contained in turps, or which are sure to be formed in it, after it (or any varnish containing it) has been kept a few weeks.

The petroleum-oils, though rather inferior to turps in solvent power for some resins, have over it an immense advantage, in their very great stability, and resistance to the action of oxygen. They keep good for years, even in the light, without ever "fattening," and may be distilled over and over again to dryness without leaving any appreciable residue in the retort.

Shale-oils (pp. 1433, 1510).—These differ from petroleum, *inter alia*, in containing amongst their lighter oils bodies belonging to the ethylene series, whose general formula is $C_n H_{2n}$. In general characters and solvent powers, they would seem to be almost identical with petroleum.

Rosin-spirit (p. 1681) is the lighter portion of the oils ("rosin-oil") produced by the destructive distillation of common rosin at nearly a red heat. Rosin-spirit begins to boil at about 110° (230° F.), but rapidly rises to 130° (266° F.), between which point and 240° (464° F.), the greater part distils over. It has no fixed boiling-point, being a mixture of hydrocarbons even more complex than coal-naphtha or petroleum. Its odour, which in the crude product is like wood-tar, but far stronger, becomes much milder and less disagreeable after refining. It is an excellent solvent, much resembling turps, than which, after refining, it is much less oxidizable.

It was known and in common use in Italy in the 17th and probably the 16th century, under the name of *aqua di rasa* or *di raggia*, and was used for thinning varnishes.

Coal-naphtha (pp. 644–5) consists of hydrocarbons, whose general type-formula is $C_n H_{2n-6}$. The lowest term of the series, C_6H_6 (benzol), boiling when pure at about 82° (149° F.), is of very important use as a solvent for various purposes, and of more limited use in certain varnishes required to dry instantly.

The next 3 members—toluol (p. 648), xylol (p. 648), and cumol, which last boils at 166° (363° F.), are very useful solvents for some of the varnishes of Div. IV., which are required to dry hard in less time than those made with turps.

Alcohols (pp. 192–214).—Vinic or ethyl alcohol (C_2H_6O), in the form of "methylated spirit," is now the chief menstruum used for all spirit-varnishes (Div. IV., Class B) and mixed-vehicle varnishes (Div. IV., Class C). The pure ("clean") spirit, in spite of the very heavy duty paid upon it, is sometimes used in special cases, where a varnish is required to leave no smell whatever behind, as the methylated spirit always leaves a faint smell, which lasts for weeks and is very perceptible where the varnished surface is extensive, or enclosed. The methylated spirit of commerce is very pure, and generally strong enough for the commoner spirit-varnishes containing only lac, sandarach, and the pine-resins; but for those containing the copals, kauri, &c., it should be rendered as nearly absolute as possible. The best method of doing this is to shake it up with about one-tenth of its weight of salt of tartar (carbonate of potash) which has been dried at a very low red heat, then letting it lie in contact with the salt for a few days. If the salt of tartar does not remain quite dry and powdery in the spirit, the process must be repeated with fresh salt of tartar, until it ceases to absorb any more water. The spirit may then be used as it is, or distilled to remove any small impurity it may have taken up from the carbonate of potash.

No spirit should ever be used in Class C, Div. IV., which has not been thus dried. Bottles or tins containing "dried" alcohol should be kept very tightly closed, or the spirit will rapidly weaken by absorbing water from the atmosphere; and the same may be said of all spirit-, or mixed-vehicle-varnishes.

Methyl-alcohol, pyroxylic spirit, or wood-spirit (CH_4O), exists in large quantity in rectified "wood-spirit" in mixture with various other bodies, such as aldehyde, acetate of methyl, &c., and especially acetone (p. 39), a body which rather assists than otherwise the solvent power of the methyl-alcohol. Its boiling-point is lower, about 66° (150° F.), instead of 78°·4 (173° F.) and its solvent capabilities are quite equal if not superior to those of common alcohol, especially when it contains acetone (as is usually the case in the commercial article), by which also its volatility is somewhat increased. Its use is now almost confined to mixing with ordinary alcohol to make it unfit for drinking.

Propyl-alcohol (C_3H_8O) is at present too dear for use in varnishes, otherwise it would have certain advantages over common alcohol, in its greater solvent power, its higher boiling-point, 96° (205° F.) and consequent slower drying enabling it to be more easily laid on with the brush. It is also less liable to "chill" in a damp atmosphere whilst being laid on. Ether, carbon bisulphide (p. 601), acetone (p. 39), chloroform, and acetic ether (p. 39), have limited use as varnish-solvents for a few exceptional purposes, especially when the varnish has to be "floated" on to the work, as in most photographic varnishes. They have very great solvent powers over resins, but the great volatility and inflammability of the first two render their use and storage very dangerous.

Besides the before-mentioned simple solvents, a considerable number of mixed or compound solvents prepared from two or more of them (one being common alcohol), are used in the preparation of varnishes with resins which are not completely soluble in any simple solvent.

Tougheners.—These should, if possible, be of the same nature as the solid constituents of the varnishes they are intended to render more flexible, so that, on the evaporation of the solvent, they may make a homogeneous mixture with the solid residue, without any tendency to separate, which would render the varnish cloudy or opaque when dry. For water-varnishes, may be used clarified honey or other uncrystallizable sugar, "over-boiled" glue (which will not gelatinize on cooling), and especially glycerine, which, being by far the most deliquescent, should be very sparingly used, or the glazes toughened with it will certainly get sticky in damp weather. In spirit-varnishes, a great many substances are used in the trade, which though very effective for a short time after the varnish is applied, are certain to lose their flexibility after a time,—such are the turpentines, and other oleo-resins, of which the most generally used is Venice turpentine, the slowest drier of them all, but still leaving the varnish brittle after a year or so, or even in a few months in a warm climate. Far superior to Venice turpentine, but rather dearer, is copaiba balsam (p. 1639), which, by reason of the large percentage (50–60), and high boiling-point, about 250° (482° F.), of its volatile oil, retains its characters for a much longer period. The best of all substances, however, for toughening spirit-varnishes is castor-oil (p. 1380), which, being colourless, never drying, and being very soluble in alcohol, would be universally used, were it not for a tendency which it is supposed by the trade (erroneously we think) to have, of separating from the dried varnish and rising to the surface as a greasy film. Linseed- and poppy-oils (pp. 1393, 1409), are also sometimes used in spirit-varnishes, and those made with mixed solvents, in which these oils are more soluble. Manilla elemi (p. 1649) is also used, but soon loses its virtues after the drying of the varnish. Its resin, however, is very hard and tough, and has, like benzoin, the property of giving great lustre to varnish.

Essential-oil-varnishes (Class A, Div. IV.) are often brittle, and require toughening. This is usually done by the addition of a small quantity of a drying oil, which, if it exceed 20 per cent. of the resin dissolved, should be previously boiled with driers. Camphor (pp. 571–8) is also used, for though a dry solid, it has the property of making varnishes flexible and tough. It is, however, supposed to have the fault of evaporating out of the varnish in time, leaving it porous and without lustre. It ought never to exceed 7–8 per cent. of the resin.

Driers.—These are substances added to, or boiled with, the drying oils, to increase their power of absorbing the oxygen of the air, and therefore make them dry much more quickly. The only ones whose reputation has survived to the present day, are the oxides and other compounds of lead and manganese.

The principal function exercised by a "drier" is that of acting as a "carrier" of the atmospheric oxygen to the molecules of oil in its immediate neighbourhood, and this action should be, so to speak, regenerative and continuous; each molecule of the drier, after giving up some of the oxygen it contains, and thus becoming reduced to a lower degree of oxygenation, should have the power of immediately retaking the lost oxygen on exposure to the air, and re-forming the higher oxide, ready to give up a fresh quantity of oxygen to the air, and so *ad infinitum.* Manganese oxide possesses this power in a very high degree, the hydrated monoxide, which, at the moment of its precipitation, is perfectly white, changes colour in a few minutes on exposure to the air, rapidly becoming brown. It is in this state that it acts most powerfully as a drier, and, when used in quantities of less than 1 per cent., makes a very pale drying oil. Lead oxide, in quantities exceeding 5 parts in 1000, gives a very dark colour to oils when heated with them to a high temperature, as in the common "boiled oil."

MANUFACTURE.—The composition of the different kinds of varnish may now be considered. Their classification is as follows:—

- Div. I.—Natural varnishes, of the Chinese, Japanese, and Indian types, containing no fixed fatty oils nor any volatile ingredients, but drying by oxidation at ordinary temperatures, and without any preparation by heat, driers, or otherwise (see p. 1692).
- Div. II.—Fatty drying oils, which harden and resinify by oxidation in the air:—
  - Class A.—Fat oils drying at ordinary temperatures.
    - Section α, in their natural state.
    - „ β, which have had their natural affinity for oxygen increased by chemical or other means, but without heat.
    - „ γ, boiled oils, which have been rendered more drying by heating, either with or without chemicals.
  - Class B.—Drying oils, dried in a heated atmosphere (stoved), japans and enamels, oiled silk, &c.
    - Section α, raw oils, alone or coloured only with pigments.
    - „ β, boiled oils, alone or with pigments.
    - „ γ, oils combined with resins, amber, and asphaltum, and oil-varnishes of Div. III.
  - Class C.—Fat oils hardened by sulphuration at high temperatures ("vulcanized oils").
- Div. III.—Oil-varnishes proper.—Varnishes containing as fixed residue a drying fat oil combined with resin, either with or without a volatile solvent or diluent, and in which the quantity of oil is greater than—or at least equal to—that of the resin.
  - Class A.—Oil-varnishes of the ancient type, containing no volatile diluent.
  - Class B.—Oil-varnishes of the modern type, thinned with a volatile solvent, but not drying hard on the evaporation of this solvent, until the drying oil in the fixed residue has become oxidized in the air.
    - Section α, in which the oil and the resin have been boiled together at a high temperature.
    - „ β, in which the mixture of oil and resin has been effected by solution or melting together at a low temperature.
  - Class C.—Black varnishes, and black japan drying at ordinary temperatures.
- Div. IV.—Varnishes consisting chiefly of a resin, gum, or other solid substance, dissolved in a volatile liquid, and drying quite hard on the evaporation of the solvent.
  - Class A.—Dissolved in hydrocarbons, alcohols, &c., boiling above 100° (212° F.)—"essence," "essential-oil," or "oleo-resinous" varnishes.
    - Section α, toughened with a drying oil, in less quantity than the contained resin.
    - „ β, containing no fat oil.
  - Class B.—Dissolved in hydrocarbons, alcohols, ethers, &c., boiling below 100° (212° F.).
    - Section α, spirit-varnishes made with methyl-, ethyl-, or propyl-alcohols.
    - „ β, varnishes made with acetone, ethers, chloroform, &c.
    - „ γ, varnishes having as solvent a hydrocarbon such as benzol, petroleum, &c.
  - Class C.—Varnishes in which the solvent is a mixture of alcohols, ethers, &c., with various hydrocarbons ("mixed-solvent" varnishes).
  - Class D.—Water-varnishes.
- Div. V.—Varnishes applied by heat or friction.
  - Class A.—Etching-ground.
  - Class B.—Heel-balls, furniture-creams, &c.

DIV. I.—Natural Varnishes.

These and the trees producing them have already been described at p. 1692. Of these, and of the methods of applying them employed amongst the natives of the countries (E. Asia) producing them, but little is known, beyond that, instead of exposing the varnished goods to warm and dry air, which is invariably required with the artificial varnishes and the drying oils, they are kept for several weeks in cool dark cellars, the atmosphere of which is made damp, by means of wet cloths hung on lines, if necessary, as though to retard the drying as much as possible.

DIV. II.—Fat oils drying by oxidation.

Class A.—*Drying at ordinary temperatures.*—Section α—In very hot and dry climates, the drying oils will, sometimes in the course of a few days, form a regular varnish when applied in very thin layers; such varnish, however, seems never to dry thoroughly hard, but retains a leathery consistence more resembling indiarubber. This, in some cases, is a positive advantage, especially where the work to be protected is liable to much alternate contraction and expansion, e. g. boats, out-of-door woodwork, tarpaulins, &c. This result is obtained in colder climates by the use of the oils of the two following sections.

Section β.—Raw drying oils have, from a very early period, possibly before the 10th century, had their drying powers increased by a great variety of methods, all of which resolve themselves in principle into two only, viz.: 1st, exposure in extended surfaces to the air and sunlight; and 2nd, combination with lead in some form or other.

Sometimes both these principles are combined, e. g. exposing to air and sunlight in shallow leaden vessels, or on the roof of a house in white glass bottles containing plates or shavings of lead, &c. The oils thus produced, though often nearly colourless and tolerably good driers, have no commercial application, and are almost entirely disused, except perhaps by a few painters of pictures. Recipes for their preparation will be found in abundance in old works on painting materials.

Section γ.—" Boiled Oils." The various processes formerly in use for preparing "boiled oil," and which will be found scattered through the older works on painting and varnish-making, are nearly all dependent on the singular power of salts of lead in causing the rapid oxidation, on exposure to the air, of the drying oils in which they are dissolved. Manganese oxide in the form of umber (a manganese ochre) was also sometimes used.

The action of lead is due partly to a similar power of easy transition between two different degrees of oxidation, aided perhaps by its greater solubility in the oil, but it evidently also exerts some other influence not at all understood, and seems, even when present only in very small quantities, to accelerate immensely the "carrying" power of oxide of manganese when used in conjunction with it. Lead oxide (or lead salts), used alone, is quite sufficient to raise linseed-oil to the highest possible degree of drying power, but it unfortunately at the same time gives it a very deep reddish-brown colour.

In boiling oil according to the old method, the action of the air is confined to the surface of the oil in the copper, and no provision is made for the renewal of that surface (so as to bring fresh portions of the oil into contact with oxygen) beyond an occasional stirring up of the litharge settled at the bottom, and the circulation kept up by the heating of the oil. In the modern process, air is forced, in as rapid a stream and as finely divided a state as possible, through the mixture of hot oil and driers, and brought into the most intimate contact with it by powerful mechanical agitation; the time of boiling is thus reduced to one-third, and the oil is less coloured. By the introduction of mixed driers of lead and manganese,—the reduction of the quantity of lead oxide from 10 per cent. to less than 1 per cent.,—and the lowering of the temperature from the melting-point of lead to the boiling-point of water, a "boiled oil" can now be produced equal in drying power to the old-fashioned lead-oil. and scarcely deeper in colour than the original raw oil.

Apparatus required.—For boiling oil according to the old method, all that is required on the large scale, is a tight-made copper boiler with a tight-fitting lid, and set in brick-work, with a furnace, &c., connected with a tall and wide chimney. This copper differs little, except in size, from an ordinary wash-house copper, but should be provided with a hood connected with the chimney, to carry off the suffocating vapours given off by the oxidizing oil. Its construction and use, with an excellent description of the old method of boiling oil, will be found in a paper on varnish-making, published in the 'Transactions' of the Society of Arts, vol. xlix., by Wilson Neil, to which the reader is referred.

For boiling oil according to the modern methods, a very different, and far more complicated, as well as much larger, apparatus is required, consisting of a copper or enamelled iron boiler of 100–200 gal. capacity, furnished with a revolving fan stirrer (with interlocked blades revolving in opposite directions), and capable of being raised to a temperature of 120° (248° F.) by a steam-jacket or a coil of pipe. It must also be connected with a powerful force-pump, by which a stream of air is forced through a ring of pipe at the bottom of the boiler below the fans, pierced with very small holes. Thus minutely divided by the holes in the pipe and the action of the stirrer, the air is most intimately mixed up with the oil, which is frothed up to nearly twice its proper bulk. The apparatus is also furnished with a dome, carrying a large exhaust-pipe leading to a tall chimney-shaft, or, better still, to the ash-pit of any furnace with a good draught.

Into this vessel, the oil is introduced, in quantity equal to half its capacity, and when it has attained a heat of 100°–120° (212°–248° F.), the stirrer is put into action, the driers (ground in oil to the utmost possible fineness) are poured in little by little, and when thoroughly mixed with the oil, the air is turned on, the heat and the stream of air being kept up for 3 or 4 hours, or until the oil, by the appearance of samples taken from time to time, is found to be sufficiently "boiled."

For lead-dried oil, and where colour is no objection, the apparatus described under the head "Linoleum" (p. 1003) may be used.

Recipes.—Almost any of the salts and oxides of lead and manganese may perhaps be used as driers, but those now almost universal, are the acetate, the protoxide (litharge, massicot, &c.), red-lead or minium (a combination of protoxide and binoxide of lead), and the carbonate or "white-lead"; sulphate, acetate, borate, benzoate, and other salts of manganese, as also its protoxide (freshly precipitated) and peroxide, or any of the intermediate oxides, and their corresponding hydrates. The quantity added may vary from 1 to 20 parts of the two metallic salts to 1000 of clarified oil; or if a lead-dried oil is wanted, from 1 to 10 per cent. of any of the above-mentioned compounds of lead, according to whether the oil is required to be merely a drying oil, or to assist the drying of other oils to which it is added.

The following examples will serve as illustrations (all the oil used is supposed to have been clarified, as described at p. 2024):—

Order 1.—*Lead Oils.*

Old process.

a. Linseed- or nut-oil	1 gal.
Litharge	1 lb.

Oil raised quickly to about 280° (536° F.), the drier added little by little, and the heat raised to 300° (572° F.) and kept so for 6–12 hours, according to drying power required.

b. Linseed- or nut-oil	1 gal.
Litharge	½ lb.
Sugar of lead	½ „

Treated as above.

The above, after having sufficiently boiled, are to be closely covered, allowed to slowly cool undisturbed for about 12 hours, most carefully poured or ladled off the dregs, and then laid by to settle for a few months, or indeed as long as conveniently possible.

Modern process.

The process described under the head Linoleum may be employed with advantage—doubling the amount of driers, and stopping the air-blowing before the oil begins to thicken; and if a pale oil is desired, lowering the temperature to 150° (302° F.) and using a copper, or enamelled-iron boiler.

Order 2.—*Manganese Oils.*

Old process.

a. Linseed-oil	1 gal.
Potassium permanganate	100 gr.

The oil is heated to about 300° (572° F.), and the permanganate of potash, previously ground very fine in some of the oil, is added little by little. The oil will froth up at each addition, and the drier will then dissolve quietly. The heat should be kept up for 2 or 3 hours with frequent agitation.

The boiler should be of enamelled iron.

b. Linseed-oil	1 gal.
Pure hydrated protoxide of manganese	½ oz.

Grind the freshly-precipitated protoxide of manganese with some of the oil, add the mixture to the remaining oil at 300° (572° F.), and keep it at that temperature till a sample begins to thicken when cold; it may then be restored to proper thinness by the addition of a little raw oil, and set by to deposit sediment.

Modern process.

The above formulæ may be used for oils treated in the modern way, as already described, at a low temperature, and with powerful agitation, with a stream of air blowing through the mass.

Order 3.—*Manganese and Lead Oils.*

Old process.

a. Linseed-oil	1 gal.
Umber	5 oz.
Gold litharge	5 „
Red-lead	5 „

Simmer together for 6 hours.

b. Linseed-oil	10 gal.
Permanganate of potash	4 oz.
Acetate of lead	4 „

The permanganate and the sugar of lead are each dissolved separately in 4 pints of water, then the two solutions are mixed together and added to the oil, cold, and with strong stirring. The oil is then heated gently until the water is boiled off, and then to about 300° (572° F.) until it begins to thicken a little (tried by cooling a drop on a piece of glass).

c. Linseed-oil	1 gal.
Borate of manganese	1 oz.
Acetate of lead	1 „

d. Linseed-oil	1 gal.
Manganese protoxide-hydrate	1 oz.
Red-lead or litharge	1 „

New process.

The same driers as above, in the formulæ *b*, *c*, and *d*, but treated, at a temperature of between 100° and 120° (212°–248° F.), with a strong stream of air blown through the oil, and powerful mechanical agitation, for about 4 hours, or until the oil shows signs of thickening when tried on glass. If wanted for "drier" to paints or other oils, the action may be carried on until the oil is nearly solid when cold, the doses of driers being also much increased. In this case, the thickened oil should be thinned with an equal bulk of turps. Processes *b* and *d* give very quick-drying oil.

Many other substances have been tried as driers for boiled oils, such as barium peroxide, mercuric oxide (red precipitate), chromic acid, lead chromate, and others, but without any satisfactory results.

Class B.—Stoved Japans and Enamels.—In this class, the oxidation of the oil is effected at a high temperature, varying from 50° (122° F.) to 150° (302° F.), and even higher where the goods to be japanned will resist the heat. The temperature must also be regulated according to the paleness or delicacy of the colours, a high temperature giving a brown colour to the oil or varnish used, for white, bright blue, pink, &c., having to be kept as low as 65° (149° F.), whereas for dark or dull colours, and brown and black, the heat may be as high as 150° (302° F.) for soldered tinware, or even much higher for iron or other goods that will stand it. The time of stoving will be, *cæteris paribus*, in inverse ratio to the temperature; thus delicate colours at 70° will take 24–48 hours' stoving, whilst coarser or darker colours at 100° or 150° will be quite hard in 6–12 hours.

The time will, moreover, vary according to the degree of flexibility and elasticity it is considered desirable that the japan should retain. Where great elasticity is required, as in japanned leather, and oiled silk, and in the tinplate intended to be stamped or blocked *after* being japanned (where the utmost degree of toughness is required), the temperature should be as low as 50°–100° (120°–212° F.), and the time, 6–24 hours. Another important factor, regulating both heat and time, is the more or less drying nature of the oil or varnish used.

When carefully carried out, and not too much forced in the stoving, this mode of varnishing can be made to yield results little, if at all, inferior to the finest natural varnishes of India, China, and Japan. The only drawback is the heat required, to which, objects of wood and some other materials cannot be exposed without warping or splitting.

Instruments and Plant.—The only essential apparatus required is a heated closet or chamber of sheet iron or other material, of dimensions varying with the business needs of the establishment, from one to many cub. yd. capacity. The principal point to be aimed at in its construction is to secure a uniform degree of heat in the whole of the chamber, together with a steady but slow draught of atmospheric air through its interior. Any mode of heating may be adopted which will give a steady unvarying heat for any length of time, and of any required degree, and at the same time be under perfect control. This is effected by the appropriate circulation of the furnace flues round (in heating by gas, they may be inside) the chamber, taking care to protect the lower portion, where the impinging heat is greatest, by a proper thickness of brick or tile.

The interior of the closet may be furnished with ledges at the sides, at various heights, to receive shelves, iron bars, wire netting, &c., to suit the size and shape of the japanned goods. The objects should be arranged as regularly as possible, leaving sufficient space between them on all sides for the free circulation of the hot air, and also to prevent the vapours given off by the heated varnish from softening the coating of japan and causing it to "run," wherever two surfaces are too near together. Very small surfaces may be nearer together than large ones. The same accident may also be caused by insufficient draught of air at the commencement of the stoving.

It is desirable that, in applying the japan, the strokes of the brush should have such a direction as will ensure their being horizontal when the object is standing in the stove, otherwise the varnish will run into vertical streaks and rollers, utterly disfiguring the work. The varnish too, unless thickened with pigments, should be itself of sufficient consistence to hold its place on the japanned surface at the heat of the oven, and when oil alone is used, it should be boiled until nearly solid, and thinned with turps to enable it to be laid on with the brush. Otherwise the coats must be so very thin as to necessitate inconvenient multiplication.

Materials.—Any drying oil or oil-varnish may be used for stoved japan, according to the required quality and nature of the result, but if oil-varnish be used, it should in all cases be highly charged with the oil; thus an oil-varnish of the Continental type (see Div. III.) will not give so tough and resisting a japan as one of the English type, in which the oil forms at least ¾ of the fixed residue.

For pale transparent japans (stoved lacquers), may be used a pale and very thick boiled oil, prepared according to the modern process, or the best and palest carriage- or body-varnish diluted with one-third or one-quarter of very old raw linseed-oil. If required to be coloured other than its natural golden colour, any transparent colour, such as lake, Prussian blue, French ultramarine, verdigris, and some of the aniline colours, previously ground in pale boiled or raw oil, may be added. Heat, about 80° (176° F.). Time, 24–48 hours, or even more.

For white, ordinary white-lead, or flake-white, or zinc-white ground in the palest boiled oil (modern process) for first coats, and the same, with the addition of the palest body-copal-varnish for the finishing coat if required glossy. Heat, below 65° (149° F.), if very pure white is required. Time, 24–48 hours.

For pale delicate colours (opaque), the same white, to which are added any pure-tinted pigments that can stand the heat, either transparent, such as those mentioned above, or opaque, such as vermilion, Naples yellow, emerald green, cobalt blue, &c. Time and heat as for white.

For dark and coarse colours, any boiled oil may be used, if sufficiently thickened with pigments or by boiling, to hold its place during the stoving, either with or without the addition of a good dark-coloured real copal- or amber-varnish.

Many of the common (so-called) "copal" varnishes made with white dammar, inferior kauri, or Manilla copal, make inferior japans. Heat, 150° (302° F.) for about 12 hours.

For pale transparent browns, nothing is finer than good amber-, or dark real copal-varnish, added to half its bulk of boiled oil, and stoved at 150° (302° F.), if the wares will stand the heat. Soft solder becomes weakened at 160° (320° F.), therefore soldered tinware ought not to be stoved at a higher heat than 150° (302° F.).

Darker browns may be obtained by addition of umber (finely ground in linseed-oil), asphaltum, Brunswick black, or "black japan" varnish. Blacks, by the addition of calcined lamp-black, or (for the best quality) finely ground ivory-black to the above browns. Heat, 150°–250° (302°–482° F.). Time, 6–24 hours.

In all cases where varnish diluted with turps is used, the japan must be quite dry before being stoved, or it will infallibly run into streaks when heated, and the greatest care must be taken to keep away dust until they are quite dry.

In japanning leather, the flesh side of the skin is scraped and shaved smooth, and rubbed to as even a surface as possible, and prepared with:—Raw linseed-oil, 1 gal.; litharge, 1 lb.; burnt umber, 1 lb.; boiled together according to old process at high temperature until the oil is much thickened when cold, and then allowed to settle and poured from the dregs. This oil, with the addition of a little burnt umber and ochre, finely ground, is well worked and rubbed into the flesh side of the leather, and the excess scraped off; it is either allowed to dry in the air, when the weather is hot and dry, or is stoved at a very gentle heat of about 40° (104° F.). Some 2 or 3 coats are thus applied, then 2 or 3 of the same oil with the addition of some finely ground ivory-black, and finally 1 or 2 of the oil alone. When all is thoroughly dry, the leather is stretched very tight, and the varnished surface is rubbed down very smooth with fine washed pumice powder, and then varnished with any of the above black japans, or asphaltum and copal oil-varnishes, and stoved at 40° (104° F.). The very greatest care must be taken to exclude dust during the varnishing, the smallest quantity ruining the varnished surface. (See also p. 1236).

Oiled Silk.—This may be prepared with 2 or 3 very thin successive coats of any boiled oil, stoved at a temperature of 40°–100° (104°–212° F.), the silk being stretched over light frames of deal laths.

Div. III.—Oil-varnishes.

The successful preparation of these varnishes is the most difficult branch of the varnish-maker's art, and requires the greatest knowledge, experience, and care, together with a skill which cannot be taught by precept, but is to be acquired only by long practice and observation. The process may be divided into two principal stages: 1st, the preparation of the resin, rendering it soluble in the oil; 2nd, its incorporation with the oil in such manner as to form a compound which shall be perfectly soluble in essential oil of turpentine, and, on the evaporation of the latter, shall dry hard within a reasonable time, and before dust has, under ordinary circumstances, been able to attach itself to the varnished surface to any serious extent.

The resins best fitted for the composition of oil-varnishes are, as already pointed out at p 2024, insoluble in any known menstrua, and are incapable of true fusion. The first effect of the application of heat to all of them, except sandarach and the very softest copals, is to make them soft and elastic like hot indiarubber. On increasing the heat, the resin, at about 300° (572° F.), begins to froth and swell up, giving off water, acids, and empyreumatic substances, chiefly hydrocarbons of various degrees of volatility, this action increasing with the heat until it has reached its so-called "fusing-temperature," and has become converted into a mixture of new and entirely different hydrocarbons, some solid, some liquid, and some gaseous at ordinary temperatures. This fusing-point is extremely high, being above the melting-point of lead, and only just below an incipient red-heat. Of the liquid products of the decomposition, some have a boiling-point but little if at all below the "fusion point" of the resin, have a very high vapour-density, and play a very important part in its successful fusion for varnish-making.

In the above enumeration of the effects of heat, the resin is supposed to have been fused in the way usual in varnish-making, i. e. confining these vapours as much as possible in a very deep vessel. The resin in such circumstances will become reduced to about $\frac{5}{6}$ of its weight, to a transparent, thin oily liquid, which may be no more coloured than pale amber, or linseed-oil, if a very pure and pale resin has been operated on. On the surface of the liquid resin, will be seen floating a stratum of heavy transparent vapour, which may be poured out like water by carefully inclining the vessel, and will condense against any cool object into a thick oily liquid of pungent though aromatic odour. If the resin, immediately on its complete fusion, be poured out upon a cool surface, it will solidify into a brittle rosin-like substance totally different in character and composition from the original resin. It is now soluble in hot linseed-oil, in turps and other essential oils, chloroform, petroleum, rosin-oil, ether, benzol, and many other hydrocarbons.

If, instead of being heated in a deep or closed vessel, the fusion be attempted in a shallow vessel such as a ladle or evaporating dish, the result will be very different. On the application of the heat, the resin will first soften and tumify as in the previous experiment, but after this, instead of fusing quietly, it will gradually become browner and harder, until it is entirely converted into a porous mass of charcoal and the aforesaid heavy vapours, which in this case are carried off with the currents of air playing round the heated ladle.

If, instead of pouring out the resin melted as in the first experiment, it be allowed to cool undisturbed in the vessel in which it has been fused, together with all the above-mentioned heavy vapours, these latter on condensing will wet the upper portion of the solidified resin, and dissolve it into a thick syrupy liquid.

From a careful consideration of the above facts it may safely be concluded :—

1st. That an oxidizing atmosphere blackens and chars the fusing resin.

2nd. That the above-mentioned heavy volatile hydrocarbons, forming a continually renewed bath of heavy vapour floating over the surface of fusing resin, effectually keep off the atmospheric air when the fusion takes place in a deep vessel.

3rd. That the least volatile of these hydrocarbons, which are liquid at the heat of the half-fused resin, materially assist in the liquefaction of the yet unfused portions, at the same time protecting the fused portions from becoming coloured by the further action of the heat.

Bearing in mind the above facts and conclusions, the reader will easily see the reasons for all the following rules and directions.

Preparation of Resin.

1. Remove outside coating of crust with a sharp knife of hard steel, if not already done by the merchant, by scraping or washing in alkaline lyes.

2. Carefully pick over the resin, setting aside the purest and most transparent and colourless pieces for the best quality of varnish, and dividing the remainder into 2 or 3 qualities according to paleness, transparency, and purity.

3. Look over each separate lot, and with the knife or with cutting nippers, remove all those portions containing earth, bits of stick, leaves, insects, and any other impurities.

4. Cut up the pieces of resin by halving each separately until they are reduced to the utmost possible evenness of size, looking like granite road-ballast in miniature, and in fragments of the size of peas or beans, or small hazel-nuts, the exact size being of less importance than evenness of bulk. Therefore it is better to sift them, through different sized mesh sieves, into 2 or 3 categories, so as to ensure sameness of size for each melting.

Fusion of Resin.

5. Place the required quantity of resin thus prepared in the melting-pot or "gum-pot" (on the small scale, in experiments on only a few oz., this may be a round-bottomed glass flask), and, if the heat is thoroughly under control, as where gas is the fuel, heat the resin very gently for some time until it has got thoroughly warmed through at a temperature of about 150° (302° F.), and then raise it as quickly as possible to the fusing-point, keeping the resin stirred and divided in all directions as rapidly as can be done with a strong metal spatula or stirrer (or, on the small scale, by shaking the flask with a circular motion), and taking care that the resin, which now froths up to 5 or 6 times its natural bulk, shall not boil over out of the vessel. This vessel should have a capacity of at least 10 times the bulk of the resin to be melted at one operation.

If the fusion has been properly conducted, the stirring active, and especially if the pieces of resin were all of nearly equal size, the last lumps of unfused resin will disappear from the frothing mass in about 10 minutes from the increase of the heat. To ascertain this, it is necessary to keep taking up samples with the spatula from time to time, and towards the completion of the fusion, this should be done every few seconds. The moment the fusion is complete, which is moreover generally announced by the sudden diminution of the frothing, the "gum-pot" is at once removed from the furnace (or the gas turned off), and preparations are made for mixing in the hot oil, if the varnish is to be made according to the mode most usually practised, which is also the most ancient. If, however, the varnish is to be made according to some process in which the cooled and solidified resin is used, as in some varnishes of Div. IV., the gum-pot must be immediately emptied, pouring out the fused resin upon metal plates (silvered copper by preference) to cool in sheets $\frac{1}{4}$–$\frac{1}{2}$ in. thick.

The oxidation and browning of the resin may be still further prevented by fusing it in a closed copper vessel through which a slow current of coal-gas is passed during the fusion.

Combination with the oil.

This may be effected in either of the three methods already mentioned. 1st, by pouring the hot oil into the resin immediately on its being perfectly fused. 2nd, by allowing the fused resin to cool and solidify, and then dissolving it in the oil by heat. 3rd, by fusing the raw resin in the oil itself, in a reducing atmosphere if possible.

The first method is that generally if not always adopted in England. The oil, raised to a temperature of about 315°–320° (599°–608° F.), is kept at that heat whilst the resin is fusing, and the moment the fusion is complete, the melting-pot is removed from the furnace, the proper quantity of oil (previously ladled out into a copper pouring vessel) carried to the melting-pot, and, as soon as the frothing of the melted resin begins to subside a little, the hot oil is poured in a thin stream and with steady stirring into the boiling resin. When all the oil has been poured in and well stirred into the resin, the melting-pot is replaced on the furnace, and the oil and resin are boiled together for a few minutes, or until a drop received on a strip of window-glass, remains transparent when cold, and does not become dull or semi-opaque. The varnish, however, is far from being finished at this stage, and would take too long to dry, besides not giving the lustrous and hard surface required of an oil-varnish, and would moreover be most likely curdled or coagulated on attempting to thin it with turps for ordinary use. To give it the qualities desired, it must undergo a further boiling at a lower temperature, in a vessel of larger dimensions and shallower form, exposing a greater surface to the action of the air, which action may be assisted by agitation, or a blast of air playing over the surface of the hot varnish. During this second boiling, may be added appropriate driers (where the varnish has been made with raw oil, and is required to dry quickly), as for boiled oil. Several meltings or "runs" of varnish of the same kind and quality are usually boiled together in this second boiling, which will take from 10 minutes to as many hours, according to the nature and proportion of the resin employed, and the description and drying quality of the varnish. The progress of the operation is examined from time to time, especially towards its termination, by placing a drop upon a strip of window-glass, and observing whether or not it looks clear and brilliant, with a lustre that is difficult to describe in words, but which is nearer "adamantine" than "resinous" or "oily" in mineralogical language. It will now also, if sufficiently boiled, be capable of being drawn out into long threads, and will feel sticky instead of oily, when the drop has cooled. When it thus "strings" well, to a length of 6 in.–6 yds., according to the nature of the varnish required, the boiling has proceeded far enough, and the varnish is completed to all intents and purposes, forming Class A of Div. III.

Wherever it is possible to apply it in this thick state (by heating the object to be varnished, or otherwise) it makes the most perfect and durable as well as brilliant of all the oil-varnishes, the subsequent thinning with turps required for allowing it to be used with the brush, having no effect on the varnish so thinned but to injure its finest qualities. This thinning with turps must be done at a great distance from any light or fire, best of all in the open air, for fear of explosions. The boiling-pot should be taken off the fire (or the fire perfectly extinguished),—the varnish allowed to cool to about 80° (180° F.), or so far as to lower its temperature to about 50° above the boiling-point of the diluent or solvent added, and the turps, hot but not boiling, poured in little by little in a thin stream, with very cautious stirring of the surface only of the hot varnish, and waiting for the frothing to subside after each addition before adding more turps.

If the varnish were stirred down to the bottom when adding the first portions of turps, there would be great danger of the boiling up becoming so violent as to almost completely empty the boiling-pot of its contents. When all the turps has been thus added, or when the varnish, on cooling a small quantity in a shallow vessel, is found to be sufficiently thinned, it is strained through a fine wire-gauze sieve, set by to clear, and stored for keeping. Varnishes thus diluted form Class B of Div. III.

The above is a rough sketch, omitting details, of the most generally used, as well as the oldest method of making a true oil varnish; by this process, any quantity of varnish may be successfully made, from a few grains in test-tubes and small capsules, to many hundredweights.

In the second method, which was brought strongly into notice (though not invented) by Tingry, in the beginning of this century, the resin is fused with all the precautions above described, allowed to solidify in thick sheets, and when cold is coarsely powdered and introduced with the *cold* oil in proper proportion, into the boiling-pot, but bearing in mind that 3 parts of the fused resin are generally about equivalent to 4 parts of raw. The resin and oil are then boiled together, and the varnish finished just as in the method above described. The varnishes thus produced differ in nothing from those made by the old process.

In the third process, the resin, which in this case may be in powder or otherwise, is introduced *raw* into the cold oil, and the whole heated with the same precautions as for fusing the resi alone.

The following will serve for examples:—

Proportions.

a. Palest amber picture varnish.

Palest transparent yellow amber	1
Palest old linseed-oil	1½
Fresh distilled turps	3

Boiled to string well at the lowest possible temperature.

b. Body copal-varnish.

Palest Zanzibar animi	1
Linseed-oil	3

Made into a varnish and added to—

Sierra Leone copal	1
Linseed-oil	3

Made into a varnish.

These are boiled together until they string well, and diluted with turps 12

c. Neil's picture varnish.

Very best African copal	1
Linseed-oil	2½
Turps	3

d. Gold-size.

Amber or copal	1
Linseed-oil	2

Boiled until it strings well, and then added to 6 parts of boiling and very drying boiled oil, and the whole boiled together until it strings very well, then diluted with 10 or 12 parts of old turps.

Class C.—Black oil-varnishes and black japans drying at ordinary temperatures.—These are merely oil-varnishes of Class B, and made in exactly the same way, but where asphaltum is used alone and without any amber or copal, they require much longer boiling.

Order 1.—Containing amber or copal.

Black Japan.

Asphaltum	6
Linseed-oil	12

Boiled together until nearly solid when cold —then add to it the following, made into a varnish—

Animi	1
Linseed-oil	2

and—

Amber	1
Linseed-oil	2

The whole then boiled together 2–3 hours, thinned with turps, and then strained.

Order 2.—Containing only asphaltum.

Brunswick black.

Asphaltum	3
Linseed-oil	4

The asphaltum is fused alone, and kept boiling for 6 hours, and in the meantime the oil is boiled with lead driers until very drying. They are then mixed and boiled until a drop allowed to cool can be rolled into a hard pill between the fingers. It is then thinned with 12–16 parts of turps, and strained.

Div. IV.—Containing a gum, or resin, dissolved in a volatile liquid, and drying hard on the evaporation of the solvent.

Class A.—Dissolved in hydrocarbons, alcohols, &c., boiling above 100° (212° F.)—" Essence," " Essential-oil," or " Oleo-resinous " varnishes.

Section *a.*—Toughened with a fat oil.

Order 1.—Resins fused and boiled with oil as for an oil-varnish, but with less oil than resin.

These varnishes are usually looked upon as oil-varnishes, but the oil being in small quantity and not the principal component of the fixed residue, and the varnish therefore drying hard on the complete evaporation of the solvent, they naturally are included in Div. IV. of the classification. They are made precisely as oil-varnishes, but require only a few minutes' boiling to get stringy, and seldom want driers. Most of the regular oil-varnishes of the formulæ published in French works on varnish-making come under this head.

a. Mixed amber-varnish.

Amber, palest	1
Copal or animi (palest)	1
Sandarach (very clean)	1
Linseed-oil	2

Fuse the resins together, add oil very hot, boil as for an oil-varnish, and thin with turps.

b. " Vernis pour equipages."

Sandarach	2
Boiled oil	1
Turps	about 3

Sandarach fused in the oil, boiled to string, and the turps added hot.

c. " Vernis blanc au copal " (Watin).

Picked copal	2
Boiled oil	1
Turps	3 or 4

Melt the copal in a glass flask, add oil very hot, boil till stringy, and add turps hot.

d. Kauri varnish.

Kauri (pale)	2
Pale boiled oil	1
Turps	2 or 3

Dissolve resin in oil, boil till stringy, add boiling hot turps, and strain boiling hot.

Order 2.—Made with previously fused resins, but dissolved, together with the toughening oil, at a low temperature in the solvent.

In this and all the following orders of varnishes, the manufacture requires no special skill or training, but can be easily carried on by any one acquainted with the roughest laboratory manipulation. Neither is any special apparatus required, beyond tins, bottles, and other storing vessels, large funnels, filters, filtering paper, stirrers, measures, and other common workshop appliances. No directions therefore need be given beyond those for choice of materials.

a. Palest fused amber	4
Pale boiled oil	1
Turps	about 6

Dissolve the oil and resin in the turps at a gentle heat—in the water-bath best, but the amber must then be powdered.

b. Animi fused	3
Very drying boiled oil	1
Turps	5

Proceed as in *a*.

Order 3.—Made with resins not requiring previous fusion for solution in turps.

Section α.—These differ from those of section β only in the substitution of boiled oil (5–25 per cent. of the resin used) for the toughener. With this difference, the proportions are similar.

Section β.—Containing no oil, but toughened with an oleo-resin.

Order 1.—Resin not fused.

a. Best mastic picture-varnish.

Palest picked mastic in tears	4
Oil of lavender	½
Camphor	$\frac{1}{16}$
Turps	8

All dissolved together in the turps at the heat of the water-bath, stirring all the time.

b. Common mastic varnish.

Mastic	1
White dammar	1
Turps	4
Camphor	$\frac{1}{16}$

Treated as in *a*, or heated in the turps until the resins melt, when they will mix easily.

c. Black dammar in fine powder	4
Copaiba balsam	1
Turps	8

Turps boiled with the resins.

d. A very cheap varnish.

Pale rosin	10
Rosin-oil	1
Petroleum, No. 3 or 4	15 to 20

Where the smell is of no importance this may be made with rosin-spirit.

Order 2.—Made with fused resin—have similar formulæ as to proportion and toughener.

Class B.—Dissolved in hydrocarbons, alcohols, ethers, &c., boiling below 100° (212° F.), "spirit-varnishes" and "ether-varnishes."

Section α.—Spirit-varnishes proper, made with methyl-, ethyl-, or propyl-alcohols, "French-polishes," and "spirit-lacquers."

Concerning these, little need be said beyond urging the use of the strongest spirit that can be obtained, in many cases further drying it by potassium carbonate (see p. 2026). Brittleness may be removed by tougheners, in the following proportions to the resins:—

	Per cent.
Cold-drawn castor-oil	5 to 10
Copaiba balsam	5 „ 20
Venice turpentine	10 „ 50

	Per cent.
Camphor	2 to 10
Oil of lavender	10 „ 25
Fat old turps	10 „ 50

Order 1.—Containing lac as the principal ingredient.

These are the hardest of all artificial varnishes, with the exception of the stoved oil-japans.

a. Pale lac varnish.

Bleached lac freed from wax	1
Methylated spirit	3

Powder the lac coarsely, and dissolve it in the spirit with a gentle heat, filter it warm, covering the funnel closely during filtration, and let it settle until bright.

b. Shell- or button-lac	8
Soft Manilla copal, palest possible	6
Copaiba balsam	2

Treated as *a*, and dissolved in strongest spirit 40

c. Lac	5
Sandarach	2
Elemi	1½
Venice turpentine	2
Spirit	24

d. Lac	6
Pale rosin, or American thus	3
Sandarach	2
Castor-oil	1
Spirit	30

e. Bleached lac freed from wax	10
Mastic	6
White dammar	4
Oil of lavender	8
Spirit	50

Order 2.—Containing little or no lac.

a. Palest soft Manilla copal	4
Manilla elemi	1
Spirit, dried	12

Proceed as in Order 1, *a*, but using the strongest dried spirit.

b. A pale cheap varnish.

Sandarach	2
White dammar	2
American thus	4
Soft Manilla copal	4
Elemi	4
Spirit	40

c. American thus	4
Benzoin	2
Manilla elemi	2
Sandarach	2
Spirit	25

Filter when dissolved.

d. Sandarach	4
Palest soft Manilla copal	4
Copaiba balsam	2
Castor-oil	1
Spirit	25

Proceed as in *a*.

Order 3.—Spirit varnishes applied with a rubber—"French polish."

These are merely lac-varnishes made rather thinner than the regular spirit-varnishes, and to which is sometimes added a small percentage of boiled oil, or copal oak-varnish. Their quality is good in direct proportion to the amount of lac contained in them, all attempts to substitute cheaper resins deteriorating the hardness and smoothness of the polish. Elemi, mastic, or benzoin, in small quantities are perhaps an improvement.

a. Seed-lac	1
Spirit	5

Shaken till dissolved, but not filtered.

b. Shell-lac	8
Mastic	2
Benzoin	1
Copal varnish	1
Spirit	[illegible]0

Order 4.—Coloured spirit-varnishes or "spirit-lacquers."

Very dilute spirit-varnishes, coloured to suit requirements and, like the last order, good in direct proportion to the amount of lac in them. They should be made with the strongest dried spirit, and where possible the work should be warmed before the application of the lacquers, and the temperature of the air between 20° and 25° (68°–77° F.), or there is risk of the lacquer "chilling," especially in damp weather. The air must also be free from dust, every particle of which will make a deeper-coloured spot. The gold-coloured lacquers for brass-work are the most abundantly used in the arts, gamboge modified with dragon's-blood being the usual and best colouring. Fancy colours may be given in every variety with any of the aniline colouring matters soluble in alcohol. Of the immense number of different formulæ for lacquers, the following will suffice as examples, all of them to be well filtered and allowed to settle till bright.

a. Gold lacquer.

Seed-lac	4
Gamboge	1 to 2
Dragon's-blood	½
Dried spirit	36

b. Deep gold.

Seed-lac	10
Turmeric	4
Gamboge	4
Dragon's-blood	1
Dried spirit	80

c. Pale brass.

Bleached lac	12
Aloes	2
Gamboge	1
Dried spirit	100

d. Bronze.

Lac	4
Sandarach	2
Gum acaroides	2
Gamboge	2
Aloes	2
Dried spirit	80

Section β.—Made with ethers, chloroform, acetone,—"ether-" or "etherial-" varnishes.

Being used only in small quantities, and for very special purposes, these varnishes may be dismissed with a few general considerations. Owing to the great volatility of the solvent, they are difficult to use with a brush, and are much better applied by "floating" or dipping. The solvents should always be well dried with salt of tartar, as described under "alcohols" (p. 2026), and, in the case of ether and chloroform, should first be well washed 2 or 3 times with an equal bulk of water, to remove excess of alcohol.

Section γ.—Made with a hydrocarbon solvent boiling below 100° (212° F.).

Of these solvents, the most powerful are the benzol and toluol series (p. 2026), which dissolve all resins soluble in chloroform (except benzoin), and many others.

Petroleum Nos. 1 and 2 yields very few varnishes, owing to its restricted solvent powers, being almost confined to mastic, white dammar, and coniferous resins; otherwise, from its great stability and cheapness, and its easy purification, it would be the most eligible of all hydrocarbon solvents.

Class C.—Mixed solvent varnishes.—In this class, the menstruum consists of alcohol, ether, chloroform, acetone, &c., to which is added $\frac{1}{4}$–$\frac{1}{2}$ their bulk of a hydrocarbon, such as turps, benzol, petroleum, &c. These solvents have their power so much increased that all varnish-resins are soluble in them, except amber and the hard copals. Where an alcohol is used as one of the components, the added hydrocarbon should be divided into two parts, only one of which is mixed with the alcohol before the solution of the resin, the second part being added to the varnish after it is completed and filtered; the risk of precipitation of the resin by the unequal evaporation of the mixed menstruum on keeping, is thus greatly diminished. All alcohols, ethers, and chloroform used in these varnishes should be well dried. As examples, the following are given:—

a. Kauri (palest)	2	
Mastic	1	
Chloroform	1	9
Spirit	3	

b. Soft pale copals	3	
White dammar	1	
Bleached lac	1	
Toluol	1	12
Spirit	3	

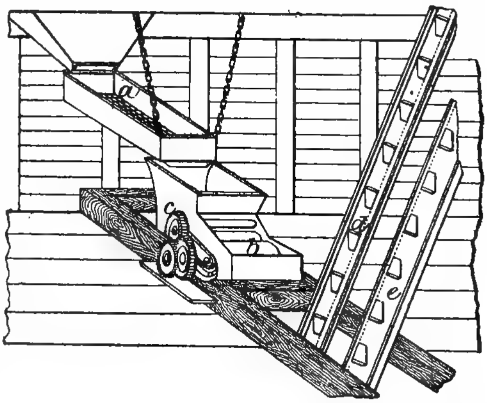
Class D.—Water-varnishes.—Albumen and gelatine being the chief ingredients in these glazes, they should, if not used immediately, be mixed with some organic antiseptic, such as carbolic acid, thymol, or salicylic acid. Borax and especially boracic acid are also excellent (inorganic) preservatives, but render the glaze rather opaque when dry, and diminish the gloss. These glazes may be coloured with any of the soluble aniline or other colours.

The author acknowledges with pleasure the great help received from E. M. Holmes, F.L.S., whose immense store of information concerning resins, &c., has always been most kindly and cheerfully placed at disposal. To Robert Finch (japanner), are also due many valuable details respecting stoved japans. E. F.

VINEGAR (Fr., *Vinaigre*; Ger., *Essig*).—Vinegar is an acid liquid, described in the British Pharmacopœia as prepared from malt and unmalted grain by acetous fermentation. The acid contained in vinegar is acetic acid ($C_2H_4O_2$), and it usually exists in the proportion of 3–6 per cent. The market description of quality is 16, 18, 24. Although the officinal prescription is adhered to by some manufacturers, the use alone of those ingredients is by no means usual; indeed, malt, in many instances, is not in the present day used at all, but for it are substituted artificial glucose ($C_6H_{12}O_6$, H_2O), and cane-sugar or molasses ($C_{12}H_{22}O_{11}$). These latter are very largely used, and as they produce, chemically speaking, the same result, i. e. acetic acid obtained by fermentation, there can really be no objection to their use. In this article, attention will be particularly given to the genuine system of manufacture, viz. from grain.

Grain or Malt Vinegar.—The commencement of the process is similar to that of beer-brewing (see Beverages—Beer, pp. 377–414). The malt and unmalted grain are first crushed (not ground, as it is often erroneously described), between steel rollers, which, revolving against each other, are so fixed that the grains shall be broken only. There are more motives than one for preventing its being ground to meal, the first of which is that great quantities of the husk would find their way into the mash-tun, and would have the effect only of supplying an undesirable amount of unnecessary vegetable matter; secondly, phosphatic combinations are most injurious, and it is in the husk that phosphates abound; while the third objection is a mechanical one, namely, that the bottom of the mash-tun, through which all the wort has to be drawn away, would, on opening the taps, be immediately stopped up. The crushing-mill is shown in Fig. 1434: *a*, tray receiving malt from the funnel above and conveying it to the roller-box *c*, whose bottom is of wire netting, to allow dust to escape; *b*, steel rollers for crushing the malt; *d e*, elevator for conveying crushed malt to the floor above.

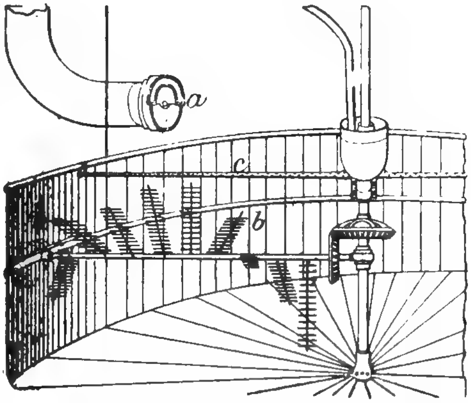
1434.



It may be observed at this point that the unmalted grain (barley, oats, rice, maize, or whatever is chosen) must be thoroughly dried on a proper kiln, previous to crushing, in order that many of the glutinous and albuminoid matters may be destroyed. Unless this precaution is adopted, there is little chance of the vinegar being sufficiently sound to withstand the deteriorating effect of the atmosphere for any time after its manufacture.

After the grain has passed through the crushing-rollers, it is transferred to a receiver (hopper) by means of a belt driven by wheels, and supplied by cups (see Fig. 1434), whence it is passed into the mash-tun, together with water heated to a temperature of about 77° (170° F.). This mash-tun is supplied with revolving forks, which, whilst revolving, move round and round the tun, and are kept in motion for about one hour. At the end of this time, the whole will have become thoroughly incorporated, and the temperature uniform. The forks are then stopped, and the mash is allowed to rest for about three hours, after which the taps are set to draw off the wort. This is immediately conveyed to the boilers, and again well boiled for the purpose of coagulating the albumen. Another quantity of water of the same temperature as the previous is then distributed over the grains by means of sparges, in order to thoroughly exhaust the grains of all their saccharine properties. The mash-tun is shown in Fig. 1435: *a*, channel conveying malt and hot water to the tun; *b*, mashing-forks for thoroughly incorporating the materials; *c*, sparges which revolve rapidly, and supply continuous and regulated streams of water for a second mash.

1435.



The components of malt (see pp. 378–9) are vegetable gelatine, diastase, &c., produced from the gluten of barley during germination, and large quantities of starch, which, in the mash-tun, is converted by the diastase first into dextrine (see pp. 1645–7), and at a further stage into artificial glucose (see pp. 1914–21).

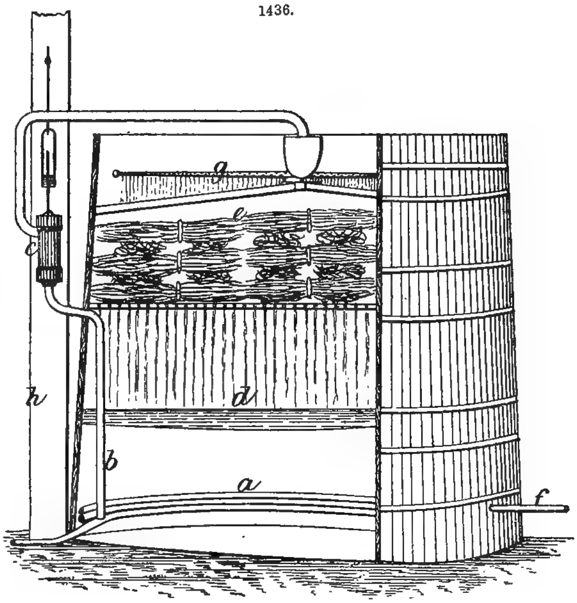
It may now be explained why unmalted grain is used together with malt. Malt possesses much more diastase than is necessary for the conversion of all the starch which it contains, and consequently requires more of that body to be supplied from a raw grain, in order to exhaust itself. It is a fact which has been stated by Ham, and verified by other practical vinegar brewers, that good sound vinegar cannot be obtained from malt alone, and the reason is undoubtedly that the superfluity of diastase remaining in the liquor produces secondary and putrefactive fermentation in the acetifier, which cannot, with any certainty, be prevented. It will be apparent from this explanation that a good calculation should be arrived at as to the proportions in which the grains should be used, and the brewer must be guided by a consideration of the quality and weight of them. The mass being converted into artificial glucose, it is passed through a refrigerator into the fermenting-tun, and yeast is added, the operation of yeast being, of course, to produce fermentation. It is at this point that the process of vinegar-making deviates from that of beer-brewing, for, whereas in the latter it is not desired to convert the whole of the glucose into alcohol, but only to the extent of about half, so that the beer may contain some sugar as well as alcohol, in vinegar-making alcohol is the only practical element required, and the fermentation is therefore forced on to the utmost by large and frequent additions of yeast, until all the sugar has disappeared, and an alcoholic solution remains.

At this point, the chemical change may be described as the conversion of glucose into alcohol, thus:—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_6O} + \underset{\text{Carbon dioxide.}}{2CO_2}$$

The fermentation being now forced to its utmost point, the wort is conveyed by pumps to other fining vats, where it is stored some days to allow it to clear itself, by subsidence, of all dead yeast and cloudiness as completely as possible, and then, passing through a filter-bed of wood-chips and shavings, into the acetifier. This is a large vat capable of holding 8000–10,000 gal., and is constructed as shown in Fig. 1436: *a*, coil of block-tin piping supplied with steam for heating; *b*, intake of pump to feed sparges; *c*, pump; *d*, surface of the article in course of manufacture, above which is a vacant space for dripping; *f*, escape-pipe at bottom of steam-coil; *g*, sparges for distributing finely-divided wort over the birch bed; *h*, support for pump. In the vat, the block-tin worm, constantly supplied with steam, is so regulated by a screw-tap that the wort may be kept at any desired temperature; the pump is made of ebonite, and entering the vat at about one-third from the top, communicates with the bottom, at about 2 in. from the actual bottom, and constantly supplies sparges which throw a continuous spray over a bed of birch. The birch is tied in bundles, and forms a bed about 50 in. deep, below which an empty space about 1 ft. deep is allowed for the wort to drip through. The object is to divide the liquid into as small particles as possible, in order that the oxygen of the atmosphere may have complete and unceasing contact with the greatest quantity.

1436.



It is to be pointed out that the birch must be freed of all juice and colouring matter by boiling in several waters, until all odour and colour are exhausted, requiring 3 days before it is sufficiently done; and the twigs must be gathered in the winter, or very early in the spring, before the sap has ascended. The temperature at which the acetifiers are worked varies but little, say 38°–43° (100°–110° F.); in the early part of the process, the higher temperature is applied, and as the acetification proceeds to its completion, it is gradually reduced to the lower. About 6 weeks' continual working is necessary for the complete acetification of each lot.

At the commencement of this acetifying process, the alcohol is converted into aldehyde in the following manner; first, oxygen of the atmosphere absorbs two atoms of hydrogen from the alcohol, forming water and aldehyde (see pp. 229–30), which latter, being formed, in its turn absorbs more oxygen from the same source, and forms acetic acid (see pp. 5–39). The presence of much oxygen is thus shown to be imperatively necessary, and on its abundance or scarcity depends in a great degree the success of the operation.

Oxygen is also necessary for the commencement of fermentation, but it is not necessary to continue it; fermentation is, however, more rapid and complete in its presence, and even light is a great assistance. It has been satisfactorily demonstrated by Pasteur and others that the exclusion of light greatly retards the fermentation of the wort and the growth of yeast. It is, therefore, advisable to ensure the presence both of oxygen and light, as slow fermentations are frequently unsound, in consequence of the unhealthy condition of the yeast, which becomes exhausted for want of opportunity to grow. This statement is supported by Schutzenberger in the following words, "When pure sugar ferments with a limited quantity of yeast, this becomes exhausted, and at last becomes unfit to effect fresh decompositions of sugar, in the absence of soluble nutritive materials."

The changes and decompositions which occur may be thus described. The first is the conversion by fermentation of glucose into alcohol, thus

$$\begin{array}{ccccc} \text{Glucose.} & & \text{Alcohol.} & & \text{Carbon dioxide.} \\ C_6H_{12}O_6 & = & 2C_2H_6O & + & 2CO_2 \end{array}$$

Secondly, the conversion of alcohol into aldehyde by absorption of oxygen from the atmosphere, thus

$$\begin{array}{ccccccc} \text{Alcohol.} & & \text{Oxygen.} & & \text{Aldehyde.} & & \text{Water.} \\ C_2H_6O & + & O & = & C_2H_4O & + & H_2O \end{array}$$

Finally, the conversion of aldehyde into acetic acid by the further absorption of oxygen, thus

$$\begin{array}{ccccc} \text{Aldehyde.} & & \text{Oxygen.} & & \text{Acetic acid.} \\ C_2H_4O & + & O & = & C_2H_4O_2 \end{array}$$

The peculiar volatile and agreeably aromatic odour and flavour of brewed vinegars, which are not to be met with in those made simply with acetic acid and colouring matter, are due to the presence of acetic ether, and volatile substances of a similar character, derived from the grains used.

The entire process of making malt-vinegar occupies a period of about 2 months, at the end of which time, the vinegar is passed away into other vats for the purpose of cleansing, colouring, and so on. The cleansing (rape) vats are supplied with beds of about 50–60 in. deep, the bottom being a layer of straw, the middle sand, and the upper shingle. Many vinegar-brewers are also British-wine makers, and their rapes are then freely supplied with spent raisins, etc., the refuse of their wine-manufacture, to enrich the flavour of the vinegar.

The natural colour of vinegar is about that of sherry, but as, in England, public taste demands a much darker colour, caramel (see pp. 598–9) is invariably used to produce it.

Formerly, the law allowed the addition of 1 part to 1000 of sulphuric acid ("oil of vitriol") for the purpose of fortifying vinegar (preserving it from decomposition), and it is a prevailing opinion that this is still allowed; but under the Food and Drug Adulteration Act, the addition of *any* quantity constitutes an adulteration.

The Quick German Process.—The "quick German" process of vinegar-making differs only from that already described in the fact that alcohol and water are used in place of the brewed material, alcohol being on the Continent entirely free from excise duty; or alcohol and water with some of the raw brewed wort to convey the volatile and agreeably aromatic odour obtained from the grain, as before explained. The usual strength of the alcoholic solution is about 15 per cent., and this is most convenient for conversion.

Where yeast is not obtainable, an artificial ferment may be produced, which will supply all requirements, by mixing wheat-flour and water into a thick paste, and exposing it, slightly covered and in a warm situation, to spontaneous decomposition, when it will undergo a series of transmutations, resembling the several actions achieved by diastase. The change will commence thus:—The mixture, in addition to converting the starch into sugar, converts the sugar itself into lactic acid, which excites vinous fermentation. About the third day of the exposure, it begins to emit a little gas, and to smell like stale milk; but this odour will soon after change its character, the evolution of gas becoming much greater, and being attended by a new scent, agreeably vinous. This will take place on the sixth or seventh day, and the substance will then be capable of exciting alcoholic fermentation.

The decomposed dough is mixed with a small quantity of tepid water, and applied to a quantity of the wort at 32°–38° (90°–100° F.), when active fermentation will begin in a few hours.

A most interesting and satisfactory experiment may be made by mixing a handful of flour into a thick paste with cold water, covering with paper to shut out dust and permit free access of air, and keeping on the mantelpiece in a warm room, where a fire is burning daily, stirring occasionally. About the seventh day it may be mixed with a mash of about 3 qt. of crushed malt and 2 gal. of warm water, or with a solution of about 10 lb. of glucose in 1 gal. of warm water, when active fermentation will take place, and the beer will be good and sound.

The explanation is that common gluten resembles diastase in the manner of its decomposition, and runs like that substance through two successive dynamic stages, first into lactic and next into alcoholic ferment.

Strong wort may also be set aside for spontaneous decomposition, after the manner of cider or perry making in the apple and pear districts, or of British wine manufacturing, when, after three or four days, it will become turbid, emit gas slowly, create alcohol, and deposit a ferment which acts on saccharine matter. If the wort be weak, however, a scum will collect on the surface, and a brown flocculent substance will be precipitated, which is incapable of exciting fermentation in sugar.

In making vinegar from alcoholic solution, it should not be much more than 15 per cent. in strength, and must be kept warm, say at 32°–38° (90°–100° F.), or at a rather less temperature than that described previously in this article when speaking of the temperature at which the acetifiers should be worked. It is quite unimportant as to whether the spirit used is new or old, and it is impossible to say with certainty what would be the loss of alcohol sustained during the operation. It is not necessary to observe any particular temperature in the rooms where the acetifiers are working, provided that the temperature of the actual article in the acetifier is kept at its proper standard.

The quality of water is also a matter of importance. Good spring water is best, but if that cannot be obtained, river water may be used, which must first be well filtered, to eliminate mechanical impurities. It is found by experience that the silico-carbon filter answers the purpose best.

The operation, watched daily and carefully, should be carried on until the sp. gr. remains constant; this is easily ascertained by the use of the acetometer. The sp. gr. of alcohol is much less than that of water; that of acetic acid, on the contrary, is greater, therefore it may be readily ascertained when the whole of the alcohol is converted.

The consequence of too little treatment would be, of course, that much of the alcohol would be lost, or rather unutilized, through its non-conversion, and the consequent deficiency of acetic acid; whilst on the other hand, if the treatment is continued after the full conversion, a large amount of the acetic acid, being volatile, would evaporate and be lost.

Too much air should not be admitted into the acetifiers, for the reason that it is not necessary, and the evaporation would be extreme; for this reason, as well as for the strength of the acetifier, and comparative facility of cleaning it, the cover of the acetifier should be of wood, instead of cloth or any such material, and the sides should certainly be closed; but a few holes about 1 in. diam. may with advantage be left in the top.

If it is wished to obtain strong acetic acid from vinegar, it should be done by neutralizing with carbonate of soda, lime, lead, or potash, and proceeding to distil with the resulting acetate and sulphuric acid, as described under Acetic Acid on p. 21.

The result, supposing soda to be used, would be explained thus:—

First

$$\overset{\substack{\text{Acetic Acid}\\\text{in Vinegar.}}}{2C_2H_4O_2} + \overset{\substack{\text{Carbonate}\\\text{of Soda.}}}{Na_2CO_3} = \overset{\substack{\text{Acetate of}\\\text{Soda.}}}{2NaC_2H_3O_2} + \overset{\substack{\text{Carbon}\\\text{dioxide.}}}{CO_2} + \overset{\text{Water.}}{H_2O}.$$

And second,

$$\overset{\substack{\text{Acetate of}\\\text{Soda.}}}{2NaC_2H_3O_2} + \overset{\substack{\text{Sulphuric}\\\text{Acid.}}}{H_2SO_4} = \overset{\substack{\text{Pure Acetic}\\\text{Acid.}}}{2C_2H_4O_2} + \overset{\substack{\text{Sulphate}\\\text{of Soda.}}}{Na_2SO_4}.$$

This process, however, is so expensive and unnecessary that it is never used.

Other Vinegars.—Wine-vinegar and cider-vinegar, sometimes found in the market, are obtained from light French and other Continental wines or from cider, as the case may be, which, turning sour from weakness in alcohol or from exposure, are put to the only remaining use, viz. making vinegar by the quick process, or exposure to spontaneous acetification, i. e. the Fielding process. Vinegar is also made from the vinegar fungus (a fungus which gradually forms on the surface of weak malt-vinegar when exposed to the atmosphere), and sugar and water; the plant is put into milk-warm water, in which sugar and treacle have been dissolved, and the whole is exposed for several weeks in a warm place. The quality of this vinegar is so inferior as to deserve no more than passing notice.

Commerce.—Our imports of vinegar in 1880 were:—From France, 32,683 gal., 3377*l.*; Channel Islands, 29,779 gal., 15,000*l.*; Germany, 12,903 gal., 4854*l.*; other countries, 7466 gal., 1137*l.*; total, 82,831 gal., 10,868*l.* The duty is 3*d.* a gal.

Bibliography.—H. Dussauce, 'Manufacture of Vinegar, and Acetometry' (Philadelphia: 1871); J. Bersch, 'Essig-Fabrikation' (Vienna). H. M.

(See Acetic Acid.)

WAX (Fr., *Cire*; Ger., *Wachs*).

The term "wax" is applied to a number of bodies, of insect, vegetable, and even mineral origin, which bear some resemblance to beeswax, the prototype of the group. Organic waxes resemble fats, in consisting of members of the series of fatty acids both free and in combination (with alcohol radicles), but differ in containing no glycerine; hard at ordinary temperatures, they soften with heat, and melt below 100° (212° F.), burning with a bright flame; they are insoluble in water, slightly soluble in alcohol, soluble in ether, chloroform, carbon bisulphide, and fixed and volatile oils; not readily saponifiable by boiling with potash, and not volatile without decomposition. The characters of earth-wax or ozokerit will be described under that head. The insects which possess the power of secreting wax are comparatively few in number, the principal being two or more kinds of bee, and a few species of coccus or some closely allied genus. Among plants, on the other hand, the production of a wax-like body is a common feature, and the bare enumeration of those exhibiting this property would occupy much space; but the number attaining commercial importance in this respect is limited to less than a dozen genera, and these alone claim attention.

Beeswax (Fr., *Cire d'Abeilles*; Ger, *Bienenwachs*).—This substance is sufficiently familiar as the material with which bees build their cells (see Honey, pp. 1127–30).

In Europe, the production of beeswax is considerable. France was estimated to afford some 27,021 metric *quintals* (of 2 cwt.) in 1873. The yield in the two Greek provinces of Calamata and Messenia in 1880 was placed at 55,000 lb., value 1080*l.* Austro-Hungary exported 7289 metrical centners (of 110¼ lb.), value 772,634 florins (of 2*s.*) in 1877; 5352 met. cent. in 1878, and 2480 in 1879. Venice exported 479½ tons, 113,786*l.*, in 1878; and 469¾ tons, 112,712*l.*, in 1879.

Almost all the countries of Asia figure as large producers. Beeswax is a commodity of great importance in all the islands of the Eastern Archipelago, whence it is exported in large oblong cakes, to China, Bengal, and other parts of the continent. No pains are taken with the bees, which are left to settle where they like (generally on the boughs of trees), and are never collected in hives; their honey is very inferior. Wallace attributes this wax to a wild bee (*Apis dorsata*), whose honeycombs are semicircular in form, and often 3–4 ft. diam. Timor beeswax is reckoned the best of the Archipelago, and is largely imported into Java for the purposes of *batikking*, or tracing patterns on cotton cloth. Beeswax may be procured in almost any quantity at Coti, Borneo; immense loads of it are brought down by the Dyaks to Seboo, where the Cambodian prows purchase it at high prices. That found in many parts of the rajah Selgic's country is perfectly white and beautifully transparent. In 1879, Sandakan exported 226 dol. (of 4*s.* 2*d.*) worth, and Sarawak, 37,330 dol. Lakhimpur (Assam) exported 19¾ tons, value 2112*l.*, in 1871. Hankow exported 325 *piculs* (of 133⅓ lb.), value 2675*l.*, in 1879; Shanghai exported of yellow wax (presumably bees'), 380½ *piculs* in 1878, and 386 in 1879; Canton exported 70¼ *piculs* in 1877 and 39 in 1878 of an undescribed wax, probably bees'; but many of the Chinese ports receive supplies of beeswax and Japan wax from other countries. Of W. Asia ports, Kastamuni sent away 50,000 okes (of 2·83 lb.), value 7500*l.*, in 1879; Brunei despatched 1695 dol. (of 4*s.* 2*d.*) worth to Singapore; and Bushire, 2500 rupees' (of 2*s.*) worth to Java, in the same year. The exports from Aleppo in 1879 were:—12 tons, 1440*l.*, to France; 15 tons, 1800*l.*, Italy; 3 tons, 360*l.*, Turkey; 6 tons, 720*l.*, Austria; total, 36 tons, 4320*l.*; in 1880:—15 tons, 1800*l.*, France; 10 tons, 1200*l.*, Italy; 2 tons, 240*l.*, Turkey; total, 27 tons, 3240*l.* Adana, in 1878, despatched 13,101 *kilo.* (of 2·2 lb.), value 965*l.* The shipments from Mersine [Musyna] in 1879 were:—40 tons, 4800*l.*, to Italy; 38 tons, 4660*l.*, Turkey; 5 tons, 480*l.*, Great Britain; 3 tons, 360*l.*, Greece; total, 86 tons, 14,480*l.*; in 1880:—67 tons, 6420*l.*, Turkey; 48 tons, 4700*l.*, France; 10 tons, 950*l.*, Austria; 2 tons, 192*l.*, Great Britain; total, 127 tons, 12,262*l.* Ghilan exported to Russia, 1346*l.* worth in 1878, and 1731*l.* in 1879.

The countries of N. Africa furnish large supplies of beeswax. The values of the exports from Egypt in 1879 and 1880 respectively were as follows:—Italy, 5900*l.*, 6773*l.*; Austria, 2600*l.*, 3625*l.*; Great Britain, 600*l.*, 1901*l.*; Turkey, 590*l.*, 358*l.*; Greece, 40*l.*, 327*l.*; France, 920*l.*, 23*l.* Tangier despatched in 1879:—250 cwt., 1750*l.*, to Great Britain; 30 cwt., 210*l.*, Spain; 24 cwt., 168*l.*, France; total, 304 cwt., 2128*l.*; and in 1880:—101 cwt., 707*l.*, Great Britain; 98 cwt., 686*l.*, France. The exports from Mogador in 1880 were:—170 bar., 2200*l.*, to Great Britain; 505 bar., 4500*l.*, France; 6 bar., 60*l.*, Spain; total, 1265 *quintals* (of 2 cwt.), 6760*l.* Algiers exported 43,000 *kilo.* (of 2·2 lb.) in 1867, and 113,000 *kilo.*, 300,000 *fr.*, in 1872; later figures were 46,160 *kilo.* in 1877, 68,644 in 1878, 30,087 in 1879. The exports from Madagascar to Mauritius were valued at 2233*l.* in 1875, 1388*l.* in 1876, and 1192*l.* in 1877. Gambia exported 60 tons in 1876, 47 in 1877, and 42 in 1878.

The New York exports were 166,703 lb. in 1878, and 28,662 lb. in 1879. Philadelphia shipped 5883 lb., value 1587 dol., in 1879. Galveston exported 54 packages in 1876–7, and 142 in 1877–8. Chili produces much beeswax, especially in the provinces of Santiago and Colchagua; the exports were 134,511 *kilo.*, value 121,058 *pesos* of (3*s.* 9*d.*), in 1870, and 98,087 *kilo.*, 83,779 *pesos*, in 1874. The Indians on the Orinoco and Amazon collect the wax of a peculiar bee, called *andaquies*, much resembling ordinary beeswax, and having similar local uses. The shipments from San Domingo in 1879 were:—164,000 lb. to the W. Indies, 19,500 Italy, 13,400 Spain, 9500 United States, 7300 France; in 1880:—126,535 lb. W. Indies, 50,400 United States, 42,250 Spain, 37,250 Italy, 4270 Great Britain. The Bahamas exported 97*l.* worth in 1876, 29*l.* in 1877, 15*l.* in 1878, and 89*l.* in 1879.

The approximate London market values of beeswax are:—American, 5*l.* 10*s.*–6*l.* 17*s.* 6*d.* a cwt.; Jamaica, 5*l.*–7*l.* 15*s.*; Gambia and Mogador, 5–6*l.*; Madagascar and Zanzibar, 5*l.*–5*l.* 5*s.*; E. Indian, 5*l.*–6*l.* 10*s.*; ditto white, 6*l.* 10*s.*–9*l.*; Australian and Cape, 5–7*l.*

Beeswax is obtained by melting the combs, after expression of the honey, in boiling water, on which it soon floats; it is left to cool, then remelted without water, and run into moulds of various sizes and forms. In this state, it is known as "yellow" or "virgin" wax, and is used for floors, and for making sealing-wax, lithographic crayons, and mastics. When bleached as described on p. 586, it is employed in candle-making and modelling figures, flowers, and other objects. The quality is mainly judged by the facility with which a sample bleaches; some, as that from the neighbourhood of Bordeaux, can scarcely be bleached at all.

Beeswax is adulterated to a very large extent, and with very numerous substances. Mineral adulterants may be detected by dissolving 1 *grm.* in 5 *grm.* of chloroform, warming if necessary. If a sediment remains, it can be examined to ascertain the constituents; turbidity of the solution when cold indicates a resinous body; milkiness, with transparent globules on the sides of the vessel, points to a vegetable wax. The presence of large quantities of paraffin is revealed by digesting with concentrated sulphuric acid at a moderate heat, by which the wax will be charred and destroyed, while the paraffin will remain floating on the acid; another simple test is the ready and complete solubility of pure wax in boiling concentrated alcoholic potash (1 part potassium hydrate, 3 parts 90 per cent. alcohol), while the paraffin will form a supernatant layer. Stearic acid is detected in the clear chloroform solution on shaking 2 *grm.* suddenly with 12–15 *grm.* of lime-water, when a lime soap forms; also by digesting the suspected sample in a dilute solution of sodium carbonate at a temperature above the melting-point of wax (say 65°–70° [149°–158° F.]). Rosin and Burgundy pitch may be discovered by adding water to a cooled boiled solution of the sample in 1 part water and 2 parts 90 per cent. alcohol, when cloudiness is produced. Vegetable waxes may be detected by boiling a little of the sample (0·3–0·4 *grm.*) in 6–8 *cc.* of water holding 0·5 *grm.* of borax in solution; genuine beeswax forms a clear supernatant fluid, while vegetable waxes produce a syrupy, gelatinous, or stiff mass, according to their proportions. Tallow may be revealed by the evolution of acrolein on boiling in a test-tube.

Carnauba-wax.—The carnauba palm (*Copernicia* [*Corypha*] *cerifera*) is a native of Brazil, growing in prodigious numbers in the province of Pernambuco, and extensively also in Rio Grande do Norte. The fan-like leaves are ranged in a tuft at the top of the hard solid stem; when mature, they are covered with a thin coating of waxy material, for the collection of which they are gathered, and laid on cloths in a cold dry place, when they shrivel and shrink, causing the wax to crack and peel off in small flakes. These flakes are collected, melted in earthen pots, and turned out when cold, forming lumps weighing 3–4 lb. each, and bearing the shape of the melting-pot. In some districts, it would appear that the young undeveloped shoots and leaves are similarly utilized, being cut before they unfold, sun-dried, powdered, and boiled, the wax then rising to the surface, and being easily gathered. The supply is very far short of what it might be. The exports from Pernambuco in 1875–6 were:—To Great Britain, 9138 *kilo.*, 312*l.*; Germany, 9530 *kilo.*, 446*l.*; in 1876–7, Great Britain, 116,872 *kilo.*, 4622*l.*; Germany, 55,108 *kilo.*, 2335*l.*; in 1877–8, Great Britain, 83,530 *kilo.*, 2958*l.*; Germany, 5952 *kilo.*, 210*l.*; 1878–9, Germany, 1542 *kilo.*, 61*l.* The exports from Ceara in 1878 were 5567 *kilo.* to England, and 12,889 to Hamburg. Liverpool imported 80 tons in 1878, 13 in 1879, and 40 in 1880. The market value ranges between 35*s.* and 85*s.* a cwt. Carnauba-wax is rather brittle, of a waxy or resinous lustre, and light sulphur-yellow colour, which, it is said, cannot be removed or destroyed; it melts at 84°–97° (183°–206° F.), according to different authorities, and has a sp. gr. of 0·99. It is largely used as a substitute for and adulterant of beeswax. The tree is valuable for many other purposes, including the fibre of its leaves (see p. 940).

Chinese White Wax, or Pe-la.—This wax is the joint product of an insect (*Coccus Pe-la*) and one or more kinds of tree, according to some, *Fraxinus chinensis*, according to others, *Ligustrum lucidum*, natives of China, notably the province of Szechuan, and in less degree that of Shantung. Whether the wax is an excretion from the insect itself, or an exudation from the tree caused by the punctures of the insect, does not seem to be clearly settled; but the operations comprised in this sort of farming are as follows. In Shantung, especially in the neighbourhood of Lai-yang, in the east, where the trees are plentiful, the insects are bred and the wax is produced in one and the same district; the insects are put out in the spring, the wax is gathered at the end of the summer, and the insects are then collected from the trees and preserved indoors until the following spring.

But in Szechuan, it is found that while the insect breeds most satisfactorily in Keen-chang, the production of wax is far greatest in the department of Kea-ting Foo. These facts are availed of by the wax farmers, who, about the end of April, convey the pregnant and wonderfully prolific females (whose pea-like appearance leads the Chinese to suppose that they are merely eggs) from the breeding district to the wax district. The journey occupies about a fortnight on foot, and has to be performed at night, as exposure to the sun's heat would precipitate the hatching, which must not take place until after the females have been attached to the trees. On arrival, 6 or 7 females are wrapped together in a palm leaf, and attached to the branches, where they soon give birth to innumerable microscopic progeny, and die. The young insects swarm over the twigs of the tree as a brownish film, but avoid the leaves. As they grow, they puncture the twigs in all directions, and the result is an incrustation of white wax.

No care is needed while the insects are on the twigs, as they have no enemy, not even being touched by ants. About the latter end of August, the twigs are cut off and boiled in water, when the wax melts and floats; it is remelted without water, and poured into deep pans, where it cools to a translucent, highly crystalline, brittle, snow-white mass, fusing at 82° (180° F.), and generally resembling spermaceti in appearance. The yield is at the rate of 2–3 *catties* (of 1⅓ lb.) of wax from 10 *taels* (of 1⅓ oz.) weight of females. The average annual value of the crop is said to amount to 650,000*l.* Hankow, in 1879, exported 6943½ *piculs* (of 133⅓ lb.), value 97,997*l.* Ichang shipped 60 *piculs*, 482*l.*, in 1878, and 438 *piculs*, 4156*l.*, in 1879. Newchwang despatched 1100 *piculs* in 1877, 762 in 1878, and 256 in 1879. The exports from Shanghai were 4432½ *piculs* in 1878, and 6542 in 1879. The wax is frequently adulterated, and often contains 15–20 per cent. of water; its uses are similar to those of beeswax, but it rarely appears in European markets.

Cordillera Wax.—The so-called wax-tree or varnish-tree of the Cordilleras (*Elecæagia utilis*) is remarkable for the quantity of green waxy matter which is secreted by the stipules that invest the unexpanded buds. This wax is collected by the Indians, and employed by them to varnish boxes, and other objects. For this purpose, it is purified by immersion in hot water; its fragility is then corrected by chewing it until it becomes ductile, after which it acquires a yellow tint, and is ready for the addition of colouring matters.

Fig-tree Wax.—A kind of vegetable wax is obtained in W. and Central Java and in S.-E. Sumatra, from *Ficus umbellata*, the *getah-lahoe* of the Malays. It is manufactured in hard chocolate-coloured lumps, melting at 60°–70° (140°–158° F.), and bleaching nearly white in boiling water; it is used locally for illuminating.

Ibota Wax.—This is attributed by A. Meyer to the influence of an insect which feeds on *Ligustrum Ibota*. It is probably identical with the ordinary Chinese white wax.

Indian White Wax.—This is produced by the female of *Ceroplastes ceriferus*, an insect allied to the *pe-la* of the Chinese, whose product is so largely used for making candles for the Buddhist temples. The Indian insect deposits its wax in small masses upon the twigs and branches of several trees, but more particularly on the *arjun* (*Terminalia Arjuna*); it does not appear to have ever been propagated, nor has the wild product been collected in quantity. Though an article of undoubted value, it would perhaps scarcely repay expenditure of European time and capital; but the natives might surely render its cultivation a very profitable undertaking. The wax is soluble, or nearly so, in boiling alcohol, also in benzine and ether, but only very slightly in turpentine and carbon bisulphide. It is found at many widely-distant points throughout Sirguja, and is abundant, and suitably situated for experimental cultivation, on the *arjun*-trees growing upon the embankment of the Purulia lake.

Japan Wax.—This is afforded by several species of *Rhus*, the most important being *R. succedanea*, which flourishes especially in the W. provinces of Japan, as far as 35° N. lat.; second in order is *R. vernicifera* (see p. 1692), which extends to 38°; and finally *R. sylvestris*.

The cultivated wax-tree (*R. succedanea*) was originally imported from the Loo-Choo Islands, but growers now distinguish 7 different varieties. The tree flourishes in great abundance on the mountainous declivities of the island of Kiushiu, and in the provinces of Higo, Hizen, Chikugo, and Chekuzen, but less plentifully in Satsuma. It is planted along the road-ways, and around the edges of most cultivated fields, except rice-land, when 2 years old, at distances of about 3 ft. between the stems; when set in squares, the interval is doubled. It is kept low by topping, and pruned to a pyramidal shape; propagation appears to be effected by shoots from the root. According to Simon, in the 5th year after planting, each tree gives 4 lb. of berries, 6 lb. in the 8th, 18 lb. in the 10th, 40 lb. in the 12th, 60 lb. in the 15th, and declines after the 18th year; 4 lb. of berries should yield 1 lb. of wax.

The tree puts forth new leaves in April, blossoms in June, and ripens its berries in October–November. The berries are of the size of small peas, united in bunches; the wax is contained between the kernel and the outer skin. The bunches are gathered, sun-dried for a few days, and stored in straw; when sufficiently mature, they are threshed free of stems by means of bamboo flails. The process for preparing the wax much resembles the local method of husking rice. A wooden tilt hammer worked by hand falls into a wooden funnel-shaped trough containing the berries. In time, the husk and pulp of the berries are reduced to powder, while the kernel remains, and can be separated by a sieve. The mass is then dropped piecemeal from a height, a current of air being blown across the path of descent to remove the chaffy husk, which is afterwards collected and worked over again. In Sikok, it is said that a small percentage of inferior wax is obtained by grinding the kernels. The sifted and fanned powder containing the wax is steamed in hempen sacks laid on bamboo wicker-work, placed over a caldron. The sacks and their contents are then subjected to considerable force in wooden wedge-presses, and the wax that escapes is moulded for the market. Sometimes the flow of wax is hastened by the application of a little *ye-no-abara*, the oil of *Perilla ocimoides*. The crude wax forms a coarse, greenish, tallow-like mass, amounting to about 15 per cent. (Simon says 25) of the weight of the berries; it is thus used for making ordinary candles.

For special purposes, the wax is refined in the following manner. It is first melted, pressed through strong cotton sacks, and dropped into moving cold water, by which means it is produced in crumpled thin flakes, ready for bleaching in the sun. With this latter object, it is laid in shallow baskets, 2½ ft. long and 1 ft. broad, placed in long rows numbering some thousands, in the open air. Here it is repeatedly turned, according to the intensity of the sun's heat, sprinkled with water, and melted again if necessary. It is then perfectly white.

For export, it is now often cast into large cubes weighing 1 *picul* (133⅓ lb.), instead of the conventional saucer-shaped cakes 4–4½ in. diam. and 1 in. thick. The chief marts for the article are Nagasaki, Hiogo, and Osaka, whence it is sent largely to China, and in smaller quantity to Europe. The total exports were 1128 tons, 43,128*l.*, in 1874; the total value in 1875 was 37,249*l.*, and in 1877 about 47,250*l.* The London market value is about 57–80*s.* a cwt. for ordinary, and 55*s.*–67*s.* 6*d.* for inferior. It is often largely adulterated with water, which it takes up when melted with it to the amount of 30 per cent. It is extensively employed for making candles and wax matches; its melting-point is 42°–55° (107°–131° F.); when old, it is soluble in boiling alcohol and warm ether, but separates on cooling. The cultivation of the shrub has been commenced in California.

Koga Wax.—This name is given by Meyer to a wax which he attributes to *Cinnamomum pedunculatum*, of Japan; it is softer than Japan wax, and has not come into European commerce.

Myrica-waxes.—Several kinds of vegetable wax are obtained from species of *Myrica*, the most important of which is *M. cerifera*, often called on that account the wax or candle-berry myrtle, though distinct from the true myrtle (*Myrtus*). *Myrica carolinensis* is much esteemed in the S. States of America, *M. caracassana* in New Granada [Colombia], *M. cordifolia, M. quercifolia*, and *M. laciniata* in the Cape of Good Hope, *M. faga* in the Azores, and *M. sapida* in China. The fruits of all these species are covered with a waxy coat, which is collected by boiling them in water, and straining the supernatant wax through a cotton cloth. The melting-point is stated at about 48° (118° F.). It is used as a substitute for and adulterant of beeswax, having a greenish-yellow colour; 4 lb. of berries are said to afford 1 lb. of wax.

Ocuba- or Otaba-wax.—Much uncertainty surrounds the origin of this vegetable wax, and there is considerable probability that it is identical with the concrete fat or wax called *bicuhiba* or *acuhiba* (p. 1379), obtained from *Myristica Bicuhiba.* Wiesner is positive on this point. The yield is stated at 18 per cent. of the fruits. The article is not yet known in Europe.

Ozokerit or Earth-wax.—There are many forms of mineral wax, all of which are hydrocarbons, mostly crystallizable, and differing mainly in the temperature at which they fuse. Generally they are met with in or near petroleum sources (see pp. 1433–47), and appear to bear a close relationship to petroleum and coal.

On the southern littoral of Lake Bal-Khash, in Turkestan, large veins of ozokerit have recently been found. Deposits exist at Monte Zolo, not far from Savignano, in the valley of the Samoggia, province of Bologna. A large quantity was lately discovered near Gisborne, New Zealand. A bed measuring 60 miles long, 20 miles wide, and 20 ft. thick has been reported to exist in S. Utah. But Galicia remains the chief source of mineral wax, the working of which deposits is inseparably associated with that of petroleum (see p. 1434). The low price of the liquid oil renders the solid wax much sought after, for which purpose, shallow horizontal levels are driven, the beds of wax often measuring only 1–3 in. thick. Much gas is evolved from the wax in working, necessitating ventilators and safety-lamps. The wax is refined for the market by melting in open or steam boilers, after being washed and cleansed at a loss of 10–30 per cent., and is then moulded in masses of 1–2 cwt. It is obtained at a cost of about 14–18*s.* a cwt., and sells when refined at 22–26*s.* The Boryslav district yielded 325,000 cwt. in 1873, and Wolanka 25,000 cwt. It is further refined, both in Vienna and in Frankfort-on-the-Oder, by means of concentrated sulphuric acid. Its chief uses are in candle-making (see pp. 589–90), for the manufacture of illuminating-gas, and as an adulterant of beeswax; its presence in the last-named article is readily detected by its indestructibility in sulphuric acid, while beeswax is entirely destroyed.

Palm-wax.—This name was given by Humboldt to the wax obtained from *Ceroxylon andicola*, a palm indigenous to the highest parts of the cordillera of New Granada [Colombia]. The wax forms a natural exudation from the trunk of the tree, whose bark is scraped (after felling) for its collection; the scrapings are boiled in water, and the supernatant clean wax is skimmed off. Each tree yields about 25 lb. The melting-point of the wax is 72°–83° (161°–181° F.). It is extensively made into candles for local use, preferably in admixture with tallow.

Petha.—This is a Punjabi term for a waxy substance which collects as a kind of bloom upon the surface of the fruit of the white gourd of India (*Benincasa cerifera*), in sufficient quantity to be collected and made into candles.

WOOL (Fr., *Laine*; Ger., *Wolle*).

Wool forms but a branch of the fibrous clothing of animals known as hair (see pp. 1093–9), and is distinguished from hair solely by being curly and serrated. It constitutes the most important textile material derived from animal sources, and demands consideration both in its commercial and in its manufacturing aspects.

Commerce.—The extent of the commerce in wool in which this kingdom is interested is shown in the subjoined table of our importations of that article in the years 1876–80:—

Countries.	Quantities in lb.					Values in £.				
	1876.	1877.	1878.	1879.	1880.	1876.	1877.	1878.	1879.	1880.
Russia	2,680,527	11,384,569	3,487,461	5,351,930	6,019,122	125,447	528,743	142,691	184,855	235,559
Denmark	2,746,462	2,041,994	1,992,413	2,538,395	2,029,379	151,542	115,855	105,154	106,922	103,361
Germany	8,371,549	9,517,450	4,560,485	4,317,818	7,173,932	577,450	585,292	296,931	261,957	399,735
Holland	3,168,297	1,610,236	2,195,134	2,636,188	2,804,905	201,668	112,404	148,784	110,751	126,601
Belgium	2,891,909	2,695,010	2,774,929	3,709,313	5,034,066	175,106	156,608	162,737	220,536	307,578
France	1,675,527	2,355,810	2,054,159	5,586,605	9,057,016	98,157	124,247	106,773	274,133	444,009
Portugal	1,559,144	1,868,999	1,864,167	1,595,232	2,964,637	76,178	93,172	90,165	70,711	143,624
Spain	6,442	169,848	288,604	399,900	1,576,097	215	5,923	7,960	17,159	62,695
Italy	87,775	64,676	45,535	42,545	320,656	5,221	4,749	2,661	1,497	14,165
Austria	117,342	24,139	21,768	85,245	531,431	5,574	1,150	1,160	3,506	20,468
Greece	560	16,207	36,302	170	99,300	[illegible]	603	1,339	7	3,975
Europ. Turkey ..	2,053,713	2,846,923	2,300,503	1,061,788	3,517,822	75,048	107,067	99,834	31,988	117,370
Asiat. „ ..	4,905,433	4,366,701	8,945,364	5,374,726	8,913,789	222,741	193,785	383,562	231,323	368,439
Egypt	3,569,808	4,438,143	2,589,859	2,725,596	2,817,342	142,340	182,849	113,107	107,921	109,105
Morocco	2,190,278	2,879,916	2,521,880	1,093,885	2,954,028	85,094	116,711	97,427	42,764	130,178
China	592,420	473,680	1,220,472	423,854	476,353	20,868	18,112	48,032	17,017	15,869

Countries.	Quantities in lb.					Values in £.				
	1876.	1877.	1878.	1879.	1880.	1876.	1877.	1878.	1879.	1880.
United States ..	343,410	418,509	938,239	190,165	713,085	21,206	23,568	44,571	8,977	34,687
New Granada ..	142,842	..	106,153	174,639	284,689	6,724	..	3,820	7,408	11,296
Peru	3,132,951	3,292,962	2,731,453	2,537,897	1,144,660	156,335	170,479	133,804	98,484	51,871
Chili	227,313	534,249	670,126	1,500,138	1,641,025	15,227	39,602	34,444	60,326	68,973
Brazil	172,230	150,263	2,117	3,619	7,559	6,147	4,624	49	126	292
Uruguay	1,005,450	940,001	771,668	75,661	426,463	47,168	35,480	28,736	3,181	22,100
Argentine Repub.	2,553,258	5,943,034	1,668,245	3,130,738	2,566,527	96,423	209,224	59,891	117,473	97,188
Malta and Gozo ..	112,846	311,977	81,391	21,928	268,166	6,126	14,563	3,045	765	10,607
St. Helena	1,200	10,000	[illegible]	7,212	9,531	40	480	12	221	331
Cape	35,424,089	32,912,225	30,670,716	36,726,410	42,226,044	2,376,322	2,224,272	2,060,345	2,267,944	2,761,852
Natal	6,734,228	8,695,553	10,285,232	9,199,884	9,159,795	379,079	618,379	568,111	602,539	479,536
Brit. India	24,453,817	21,566,074	27,032,725	22,202,554	29,190,049	986,672	853,820	1,030,394	773,780	1,123,552
W. Australia ..	2,349,813	2,466,530	2,396,540	2,523,913	2,831,986	142,504	150,039	146,202	157,689	179,833
S. Australia . ..	38,117,850	43,684,778	44,028,326	46,181,518	44,799,118	1,753,618	2,043,939	2,081,538	2,158,932	2,165,858
Victoria	96,930,460	103,351,169	94,340,389	93,655,501	94,512,721	7,188,480	7,486,916	6,598,508	6,614,471	6,507,765
New S. Wales ..	53,445,792	57,651,282	54,534,117	64,059,824	76,965,651	3,317,202	3,533,957	3,290,046	3,800,542	4,722,782
Queensland	14,402,214	13,983,858	15,959,679	14,018,302	13,549,431	848,996	843,907	930,316	816,168	839,130
Tasmania	6,037,883	6,435,573	6,319,080	6,923,363	7,003,007	397,390	419,242	410,680	448,176	436,049
New Zealand ..	52,585,145	53,673,873	58,594,062	60,437,190	60,964,640	2,997,579	3,112,469	3,238,026	3,330,076	3,503,675
Canada	65,980	62,200	406,159	90,982	24,536	2,991	4,514	23,012	3,920	1,420
Falkland Is... ..	854,164	911,259	1,335,798	1,123,444	1,633,971	42,212	45,955	66,557	47,797	75,493

The manufacturing qualities and varieties of wool are more conveniently dealt with under the article Woollen Manufactures (see pp. 2049–57).

WOOLLEN MANUFACTURES (Fr., *Industrie lainière*; Ger., *Wollmanufactur*).

The pages of history afford ample testimony that the manufacture of wool was one of the earliest occupations, and probably the first textile industry in which mankind engaged. The early domestication of wool-bearing animals affords presumptive evidence in favour of this conjecture. Though pastoral and agricultural occupations have most likely existed side by side from the remotest times, the former would allow more opportunities for observation and reflection than the latter, whilst the natural covering of the sheep and the goat could hardly fail to suggest its utilization for clothing purposes. Agriculture, on the other hand, would require to be followed for a considerable time before the uses of fibre-bearing plants would be discovered, whilst, from that point, great steps in progress would be needed in the preparation and application of the product before these respective ends could be attained.

The manner in which the evolution of the utilization or manufacture of wool proceeded may easily be conjectured. Sheep and goats, from their comparatively defenceless nature, their large numbers, and the rich and abundant supplies of food their milk afforded, would soonest become subject to domestication. It does not appear that in early days their flesh was eaten or otherwise availed of. The wool annually shed would probably be collected in the first instances by the shepherds, to afford a soft and warm covering whilst tending their flocks at night. This would lead to its transfer for the same purpose to the dwelling-place of the family. As population increased, and nomadic habits were engendered by the necessity of seeking fresh pastures for the flocks and herds of the patriarchal races of mankind, they would be led to leave the plains and valleys, and seek the uplands and mountain plateaux, where pastures remained green and water was abundant during the heat of summer. Here, the normal temperature being so much lower, and that of the mountain plateaux especially being sharp and keen, would render personal clothing welcome, if not a necessity. What so accessible, readily adaptable, and so perfect, as the skins of sheep and goats? Hence their adaptation for clothing and tent purposes, for which uses they have hardly been yet discontinued. Subsequently, the felting property of wool was discovered, probably by observing its tendency to become matted in that manner on certain parts of the animal under peculiar conditions. Amongst the nomadic tribes of Central Asia, felt fabrics are still in extensive use for the construction of tents.

That the textile arts were invented during the prehistoric period, is an undoubted fact, and one that fully accounts for the little that is known of their origin. There are many claimants amongst ancient nations for the honour of their invention, but when the best and most authentic testimony is impartially weighed, it seems to point to the conclusion that the award is due to Egypt. Few persons can be dissatisfied with this result, because that country at the dawn of recorded history was already in the enjoyment of a high degree of civilization. Singularly enough, it is also the only country which gives us tangible proof of the excellence to which the art of spinning and weaving had attained in remotely ancient times. We owe this evidence to the curious custom, prevalent in that country, of embalming the dead, in which process the bodies were swathed in numerous folds of cloth. This cloth is in many instances of the most beautiful texture. It is in all cases composed of linen, and not of cotton, as was once generally believed. Usually it is found torn into strips or filleting, and wound spirally around the bodies. Recent discoveries of mummies of kings belonging to the earliest dynasties that ruled over the country have carried this demonstrative evidence several centuries further back than was previously known. Though the cloths thus singularly preserved are all composed of one textile material, it derogates nothing from the strength of the assumption that at least equal excellence had been attained in the manipulation of wool. We have ample testimony that the sheep was a highly esteemed animal in Egypt, constituting there as elsewhere the chief element of wealth. The utilization of its fleece would be obvious.

Whether spinning or weaving was invented first, is now hopelessly beyond discovery, though the conjecture may be hazarded, with a great probability of truth, that it was the latter. The form it would probably assume would be the interlacing of vegetable reeds obtained from the banks of rivers, which art in some places has survived to the present day. The discovery of a method of making a continuous thread from short fibres, most probably wool, by draught and torsion, would place a highly increased power in the hands of the weaver, and enable him to produce a fabric of greatly enlarged dimensions. The art of spinning is one of the most important developments of human ingenuity, and has probably contributed more to the comfort and happiness of mankind than any other single invention. It would be interesting, if possible, to divine how it occurred. There is a probability that the world is indebted for it to some ancient shepherd boy, who, whilst reclining in the shade with his flock grazing around him, laid hold of a stray lock of wool within reach, and amused himself by pulling it into a light mass; maybe he then began to twist a few of the fibres between his fingers, drawing them out at the same time, and observing that he could thus produce a continuous thread. He may or may not have realized the fact that he had made a great discovery: probably not. Assuming the correctness of this supposition, the first thread was woollen, not worsted—a difference that will be explained subsequently.

At the dawn of the historic period, the twin arts of manufacturing flax and wool rise into view together, showing a parallel advance. At that time, the Egyptians had so far perfected and organized the industry, that rudiments of the modern factory system are discoverable amongst their remains. These are found in the paintings on the mummy coffins and the interiors of their tombs. That wool was one of the materials extensively wrought up into fabrics, scarcely admits of a doubt, and the fact that no specimen of the cloth has come down to modern times probably arises from the certainty that its nature unfitted it for the particular use that has preserved the linen one. With a linen fabric, the dead could be swathed much more firmly and closely than with one of wool, owing to the perfectly extended form of the fibres in the former, whilst the latter can scarcely be freed from its natural curvature. During their sojourn in Egypt, the Israelites acquired a knowledge of the native spinning and weaving as there practised. On their departure, and during their wanderings in the wilderness, it is stated that, on the occasion when contributions were being made for the construction of the tabernacle, the women who were wise-hearted spun with their hands, and brought in the yarn, the blue and the purple, the scarlet and the fine linen, which others were inspired to work up into suitable fabrics. A prohibition issued during the same period incidentally reveals that union fabrics were customarily made even at that early time, for it is ordered that "a garment mingled of linen and woollen shall not come upon thee." The sacred writings, through all the subsequent history of the Jewish nation, afford plenty of testimony to the high development of the textile arts, not only amongst themselves, but also among neighbouring nations, the Egyptians, Assyrians, Babylonians, Phœnicians, and others. In a similar manner, classical writers reveal the condition of these arts amongst the Greeks, the Romans, and their contemporaries, the less civilized nations who successively fell under the influence of their dominion. In a previous article (Linen Manufactures), their progress has been traced, and as the manufacture of wool and flax appear to have always advanced hand in hand, any further detail here would be needless repetition.

The instruments in use were the same for both industries, being the distaff and spindle for spinning, and, as occasion required, both the vertical and the horizontal loom were employed. All improvements that took place subsequently were equally applicable to both purposes, and were adopted by both classes of workers as quickly as the limited means of communication permitted. Coming down to modern times, in which more nicety of manipulation has been attained, a greater divergence in the processes has been introduced, arising from more regard being paid to the essentially different nature of the two materials, wool and flax. During the current century, a great advance has been made in the productive capacity of the woollen industry, owing to the introduction therein, with the necessary modifications, of the remarkable inventions that have distinguished the growth of the cotton trade, and have placed it in a position of such notable eminence. This example has also been of indirect benefit to the woollen industry, by stimulating independent invention, which has not been inconsiderable of late years.

The manufacture of wool, including in this term all cognate fibres, is, after cotton, the most important textile industry of Great Britain. The raw material consumed in the manufacture is chiefly composed of the following:—All varieties of sheep's-wool, alpaca, mohair, goats' hair, and camels' hair; in addition to these, are several minor articles, the most important being shoddy, mungo, and extract, all of which are manufactured wools, produced in a manner to be explained hereafter; and such fibres of vegetable origin (cotton, flax, China grass, rheea fibre) as, with silk and silk waste, are consumed in the production of union goods, and generally form the warp of the fabrics.

The industry is separated into two great divisions, primarily dependent upon: (1) the class of wool, and (2) the method of manipulation. To a certain extent, the first dictates the second. These two are the woollen and the worsted trades, each being subdivisible again into several minor branches.

The woollen industry takes for its raw materials chiefly the fine, short, felting wools, technically denominated "clothing" or "carding" wools, to which are added the manufactured wools: "shoddies," "mungos," and "extracts," the nature of which will be explained subsequently. Along with these, in the formation of union goods, silk, and the several vegetable fibres before named, are consumed. From these, are produced the fine cloths of the West of England, Leeds, and other places, and those of several centres on the Continent; the heavy fabrics of the Huddersfield districts; the tweeds of Scotland and Ireland; and the shoddy cloths of Dewsbury, Batley, and Morley, which include all ranges and qualities, from the finest to the coarsest, and the lightest to the heaviest, for male and female wear.

The worsted division, for its share of the raw materials, claims all the long, or "combing" wools, as they are termed, represented by the wools obtained from the Leicester breeds of sheep and the varieties which have been developed from them. Mohair from the Angora goat, the fleeces of the llama, alpaca, and vicuna, and similar animal products, are also included in this division. These are supplemented by the same class of vegetable fibres and silk as in the preceding division. The product from them consists of an extensive series of light goods, having very numerous designations, but substantially consisting of fabrics that generally may be termed "lustres," "mohairs," "alpacas," "llamas," &c. Union cloths from each of these fibres are also made, silk or cotton, and occasionally other materials, being employed for warps. Bradford is the centre of the district producing worsted goods in all varieties, whose values extend from 3*s.* down to 2*d.* a yd. for low union goods. Formerly Norwich was the centre of a great trade in worsteds, but its importance has been declining for a long time past. Fashion and other causes have also conspired to depress the industry and commerce of Bradford and district during the past few years, so that comparatively little enterprise has recently been exhibited, save in individual cases where efforts have been made to adapt the machinery to the production of the softer classes of fabrics now extensively in demand.

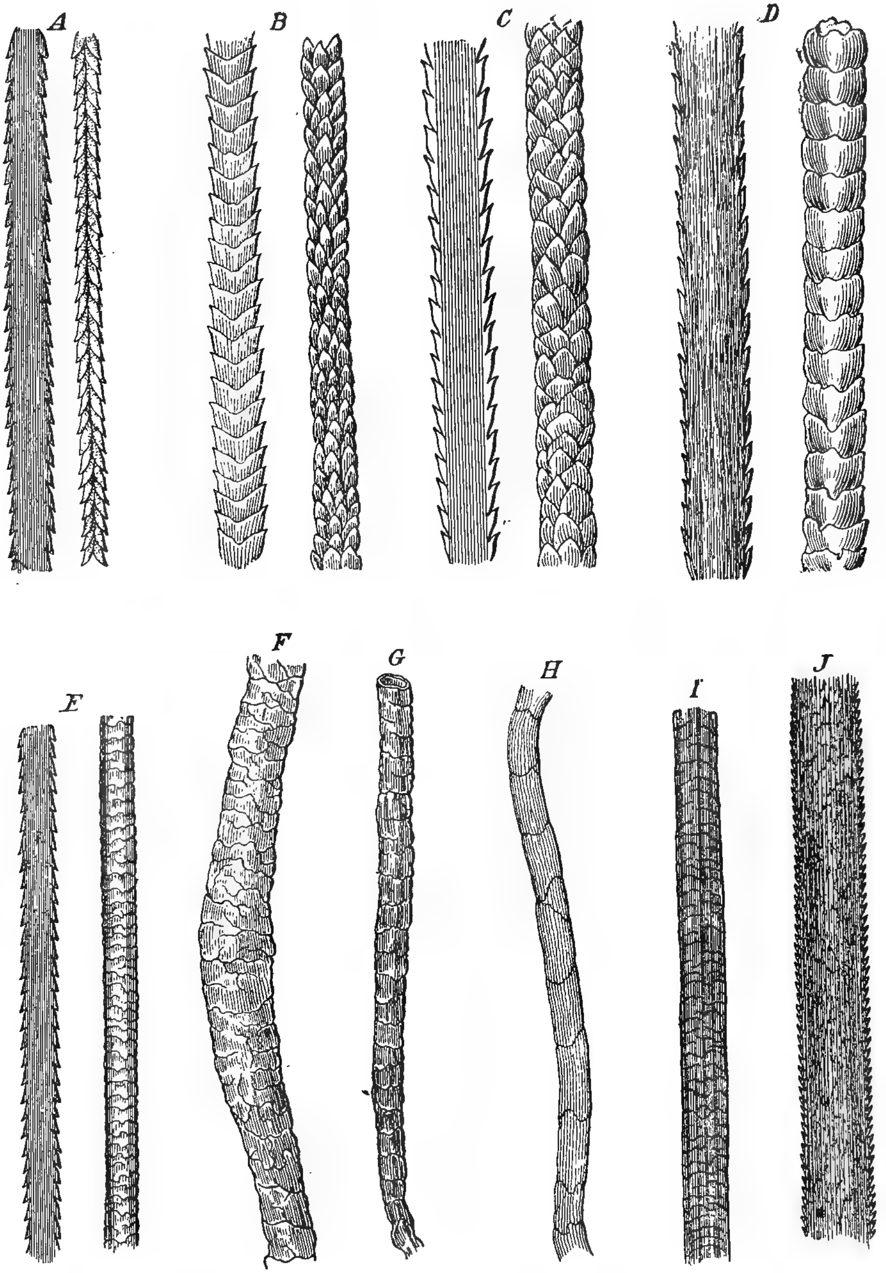
Structure of the Fibre.—The mechanical structure and chemical composition of the wool fibre constitute its most important manufacturing characteristics. In every process during its fabrication into textures, regard must be paid to these, but especially to the first-named; the second, which makes it a bad conductor of heat, is the quality that peculiarly fits it for use as a material for clothing purposes, particularly in temperate and cold climates.

The mechanical structure of the wool fibre always formed the chief basis of its commercial value, even before its true nature was discovered. Though wool has been in use for its present purposes during several thousand years, and its valuable properties have been known for the same time, the peculiar structure on which these properties depend has only recently been discovered. The circumstances connected with this interesting event, which took place on the 7th February, 1835, are fully narrated by W. Youatt, in his valuable treatise upon sheep. In the course of his inquiries, he directed his attention to the nature of wool, in order to discover the cause of its felting property, and called in the assistance of Powell, an artist engaged in the manufacture of the best microscopes known at that time. Their efforts were rewarded with complete success, as the microscope revealed all details of the construction of the wool fibre. The same instrument has been further utilized for the purpose of discovering the minute differences that, judging from the varying effect produced in the manipulation of various kinds of wool, it was inferred must exist. These have been recorded by many inquirers, and the sum of the information thus obtained agrees almost perfectly with the results of experience.

The wool fibre is curly, and to a certain extent elastic. Its surface is covered with scales or imbrications, differing in number and shape according to the species and even variety of the animal from which the fibre has been obtained. The most important differences also exist in the fleece of the same animal, which fact renders necessary the process of sorting. Between wool and hair, the differences are even greater still. In the latter, the scales or imbrications are so imperfectly developed, even if in some sorts they exist at all, that the article until quite recently has been incapable of use in the same way as wool. Recent improvements in the manipulation have, however, led to the successful introduction of hair for purposes of admixture with wool, and its use is now rapidly growing. Those which have been received with most favour, and have, either alone or mixed, been most successfully used, are the hairs of the alpaca, the llama, the vicuna, the Angora goat, and the camel, which are all more nearly allied to wool in structure than other animal hairs. Fig. 1437 sufficiently illustrates the mechanical structure of the wool fibre, and its variations in the different varieties of sheep.

The figures are to some extent typical: A is from a fleece of the celebrated merino variety of sheep, for which the modern world is so deeply indebted to Spain; the characteristics of this wool may be summed up briefly as follows: staple, short; quality, very fine; colour, generally white; most suitable for carding purposes. E is a fibre of Saxony wool, the animal yielding it being a sub-variety of the preceding, a cross between the merino and the best native sheep of Saxony. The wool produced by these animals demonstrates the advantage of high and careful culture, being classed along with Silesian, a similar sub-variety of the merino, the finest wool in the world. Its characteristics resemble those of A. It is sometimes used for combing purposes. The Southdown

1437.



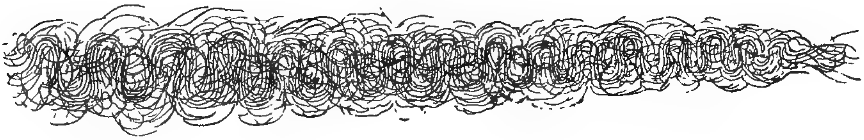
(B), and those breeds of which it forms the basis, constitute a variety of the common sheep. Its wool is in all cases short and fine, except where it has been purposely crossed with long-woolled varieties in order to procure a medium wool. The product is used for both combing and carding. The Leicester (C) and Lincoln (D) represent our long-woolled varieties of sheep. The staple is long, and the quality ranges from coarse to very fine. In Yorkshire, Nottingham, Lincoln, and Leicester, these two varieties yield a highly lustrous wool, approaching mohair (H) and alpaca in brilliancy. These are technically known as "lustre" wools. So far as is known, this wool can only be grown in the four counties above named. When the pure Lincoln or Leicester sheep are transferred to other countries, or even other parts of England, the fleece rapidly loses its brilliancy. Common wool (F), goat-hair (G), cow-hair (I), and human hair (J), are also shown. The carding or short wools are distinguished by a finer fibre and a greater number of imbrications per lineal inch, Saxony and Silesian wools being only $\frac{1}{800}$–$\frac{1}{900}$ in. diam., 3–3½ in. in length of fibre, and having 2700–2800 imbrications an inch. Merino falls a little below these, and Southdown as much further, the last-named being $\frac{1}{600}$ in. diam., and having only about 2000–2100 serrations in an inch. When a wool fibre has a less diameter than $\frac{1}{500}$ in., it is denominated a coarse wool, and so regarded in the trade; as the length of staple increases, the number of imbrications diminish. These changes render it unfit for clothing purposes, as its felting property is thereby reduced.

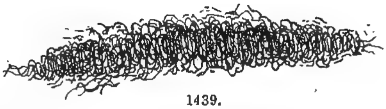
It is believed that the method of growth of the wool fibre is somewhat as follows. The skin of most animals is organically formed for the production of hair, in this term including wool. The length and thickness of the hair is regulated by a law of nature, and is perfectly adapted for its purpose, changing in several respects in the different parts of the body. The shape varies in different animals, but is generally cylindrical or oval. The tip of the hair at first is conical and pointed, this being, as is well known, the distinguishing characteristic of the first or "hogget" fleece of sheep. When left to nature, wool- and hair-bearing animals cast their coat at appropriate seasons, and soon assume a new one. This seems to be caused by a cessation of activity in the secreting glands at their base or root, whereby the hair becomes detached, and is cast off. After a period of rest, the secreting and excreting functions of the glands are resumed, and the new covering soon becomes visible. Domestication of animals, especially when shearing the fleece or clipping the hair becomes habitual, interferes with the natural intermittent activity of the hair-glands, which instead become persistent, and the growth continuous. In the human subject, to which more attention has been given than to animals, and in which the growth of hair is closely analogous, it has been found that at the bottom of each hair-tube is a small conical prominence, like a papilla of the sensitive layer of the dermis, with which latter it is connected by means of the walls of the sheath or hair-tube. This cone is the producing organ of the hair, and possesses a large number of capillary vessels and nerves. The hair-pulp is secreted in this cone, and, being poured out, is first converted into granules, and next into cells, which are subsequently modified to constitute the texture of the hair. The cells contain the pigment upon which the colour depends. In the structure of the hair, a threefold modification of the cells takes place.

Around the central cells, the next layers, comprising the chief thickness of the hair, by a process of lengthening and splitting, common in the economy of cells, are converted into fibres, and quite at the outer circumference a thin circle of cells is flattened into the form of scales, like those of the scarf-skin. The arrangement of these scales is seen in the Merino, Southdown, and Leicester varieties, to be like that of the scales of a fish, though with less perfect regularity, and such differences as result from their being arranged around a cylindrical or oval form. They are the largest and most perfectly developed in the Lincoln, Leicester, and Southdown varieties. In the Merino, the same perfection of arrangement is preserved, whilst they increase in number and diminish in size. Less regularity obtains in the Saxony, though the number further increases. With the larger diameter of the human hair, the scales are still less in magnitude, though greater in number. These observations lead to the conclusion that the order of growth is probably as follows:—(1) The secretion of the fluid obtained from the blood; (2) its discharge from the gland; (3) its conversion into granules, and then into cells distended with fluid; (4) its protrusion to and through the exterior skin, where, on contact with the atmosphere, the outer layers of cells lose their liquid contents by evaporation, the cell-walls collapsing and flattening, so as to form the scales shown in such great numbers. This shrinkage of the cells causes the upper edges of each layer to overlap the base of those of the preceding one, thus composing the beautiful arrangement revealed by the microscope. The shrinkage being simultaneous all round the cylinder which forms the hair, the outer circles of cells form, as it were, a series of cups, the base of the upper one being inserted in the top of the lower one, by which in succession the hair is built up. Each cup is composed of the number of scales or collapsed cells required to form the circumference of the cylinder, and these having been globular, their arrangement in circlets gives the serrated upper edge to each cup. It is this peculiar mechanical structure of the wool fibre that adapts it so admirably for the purposes to which it is chiefly applied, as therein lies its felting capacity.

This, though perhaps its chief characteristic, is not its only one; another of hardly less importance is the spirally curling form of the fibre. Superficially, this constitutes the main distinguishing quality between hair and wool. If a lock of wool be closely examined, each fibre will be seen to be twisted in a spiral direction from the base to the tip. The number of convolutions is greater in the fine or clothing wools than in the long or combing sorts. The processes through which wool is put in manufacturing woollen goods would to a great extent eliminate the curl of the long fibre; but the greater number and the shorter space occupied by the curl of the short wools allows them to be retained, by which means it is admirably adapted for the production of a woollen thread, which has to be fulled or partially felted in a subsequent stage. The more perfect parallelism of the fibres that would result in a yarn made from long wool would prove a great, if not an insuperable, obstacle to the satisfactory performance of the felting process. Figs. 1438, 1439 show this characteristic in both the clothing and combing varieties of wool.

1438.





1439.

The felting quality of wool, though known for centuries, or even thousands of years, was not thoroughly understood until the structure of the fibre was microscopically examined. It may even be questioned now whether the fact is yet fully explained or not. The allegation that it is owing to the short curled lengths of the fibre (when spun into yarn or retained in the mass) offering facilities for an interlocking of the fibres by means of the scales and convolutions, is not quite satisfactory. The theory may fully account for the interlocking or entanglement of the fibres, but it leaves unexplained the principal characteristic of felting, viz. shrinkage. A woollen fabric, when subjected to moisture and warmth, shrinks in every direction in a manner which the mere interlocking of the fibres does not sufficiently explain. The first subjection to this operation does not exhaust the property; it may be repeated frequently, and the article will on every occasion be further reduced in dimension. The introduction of acid into the bath in which the fabric may be dipped greatly accelerates the process, and increases its extent, as is familiarly seen in the manufacture of felt cloths or hats. This is not in any way indebted to the milling process, though working the wool by the hands may be regarded as an equivalent. But this felting or shrinkage takes place without any such action, as, for instance, when cloth is dipped into water and hung up to drain in order to "shrink" it, as the process is technically called, before it is cut up for garment purposes. A similar result ensues, though to a less extent, in the cases of fabrics made from "non-felting" wools, as they are sometimes erroneously termed, when such articles are inadvertently left in water, especially if the water is hot. The same effect is seen in the case of dress fabrics of worsted materials, when the wearer gets caught in a shower of rain. Too often have such materials "run up" to such an extent as to render the dress unwearable afterwards; and partially to this fact may be attributed the present unpopularity of Bradford goods.

It is proverbially easier to offer objections to an accepted theory than to propound a better, but it may be pertinent to observe that experience shows moisture to be essential to felting, and that the process is expedited and carried to a greater extent at a high temperature, or when the water employed is hot. It appears probable, therefore, that the wool fibre is partially dissolved, especially that part which contains the original cells still retaining their contents. The walls of these cells, bursting by the heat or mechanical action, or a combination of both, and their contents being discharged, shrinkage naturally takes place. The scales of the separate fibres, being in contact with one another, or already entangled, the fibres are drawn to each other, as it were, by a firm embrace. Probably also the circlets of scales forming the series of cups of which the fibre appears to be composed may at the same time, and by the same cause, be rendered capable of sliding more deeply one into the other. The pressure being exerted in each direction by the entangled scales of the individual fibres, each of the latter is shortened in a corresponding degree, and shrinkage in every direction results thereby. This conjecture may be held to be supported by the fact that fine wools, which contain the greatest number of imbrications, are the best felting wools.

Varieties of Wool.—Almost every year is adding to the varieties of commercial wool, new kinds being continually introduced, either from new sources of supply, or as the result of assiduous and careful culture. The following table, constructed with great care, and corrected by some of the most eminent wool merchants and experts in this country, has been drawn up and published by Professor Archer, F.R.S.E., and will convey some idea of the numerous kinds of sheep, and the differences in the quality of their fleeces:—

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP.

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
1. Spanish (*Ovis Hispaniam* of Linnæus).	Spanish	..	..	..	..	..	..	Used in Leeds and Huddersfield.
	Class 1, Estantes or Stationary.	..	short	fine	black and white.	4–5 lb.	carding	Spanish wools obtained from the plains are of the merino kind, and are chiefly used for woollen goods; but that obtained from the mountains is coarse and of unequal quality, and is used for various low-class goods.
	a. Churrah	..	long (8 in.)	rather coarse.	white	..	combing	
	b. Merino	..	short	very fine	white	ram 8 lb. ewe 5 lb.	carding	
	Class 2, Transhumantes or migratory.							
	a. Leonese Negrettes.	..	short	fine	black, white, and grey.	..	carding	
	Escurial or Estremadura.	..	short	finest	white	..	carding	
	Guadeloupe	..	short	very fine	white	..	carding	
	Paulars	..	short	good	white	..	carding	
	Infantados	..	short	coarse and hairy.	white			
	b. Sorian							
	Swedish	Merino and native.	long	soft, fine	white			
	French	Merino and Roussillon.	long	soft and very fine.	white	9 lb.		
	Danish	Leonese and native.	medium	fine	white	..	combing and carding.	
	Saxony	Merino and best native.	short	finest	white	..	combing and carding.	
	Prussian	Merino and native.	short	very fine	white	..	combing and carding.	
	Silesian	Merino and native.	short	very fine	white	..	combing and carding.	Silesian wool is almost, if not quite, the finest in the world.
	Hungarian	Merino and native.	short	fine	white	..	carding	
	Hanoverian	Merino and small native.	short	very fine	white	ram 4 lb. ewe 2¼ lb.		
	New South Wales.	Merino and Southdown.	..	fine	white	2¼ lb.	combing or carding.	
	„ „	Merino and Leicester.	..	fine	white	3 lb	combing or carding.	
	W. Australia	Merino and Leicester.						
	British (pure breed).	Merino and Southdown.	..	fine	white			
	British (ditto)	Merino and Leicester.	..	fine	white			
	„	Merino and other native breeds.	..	fine	white			
2. Common Sheep (*Ovis rusticus* of Linnæus).								
Sub-variety (*a*), Hornless or Lincolnshire.	Lincolnshire	Lincoln and Leicester.	long	good and glossy.	white	8–9 lb.	combing	These are amongst the finest of the long-stapled or combing wools.
Sub-variety (*b*), Muggs and Shetland.	Shetland	..	long	very fine	..	..	combing	
Sub-variety (*c*), Ryeland.	Herefordshire	..	long	medium	white	6–7 lb.	combing	
Sub-variety (*d*) Southdown.	Sussex	..	short	fine	white and grey.	3–4 lb.	combing and carding.	Hoggets are valuable, and the long qualities are used in Bradford; the shorter ones in Rochdale for flannels.
	Kent	Southdown and Romney Marsh.	short	medium	white	3–4 lb.	combing and carding.	
	Hampshire	Southdown and old blackfaced Berkshire.	short	fine	white	4 lb.	combing and carding.	

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
Sub-variety (*d*), Southdown—*continued.*	Berkshire	Southdown and old blackfaced Berkshire.	short	fine	white	4½ lb.	combing and carding.	
Sub-variety (*e*), Old Norfolk.	Norfolk	Southdown and Norfolk or Downs.	short	fine	white	3½ lb.	combing and carding.	For flannels and low cloth.
		Southdown and Leicester or Norfolk half-breeds.	medium	medium	white	6 lb.	combing	
Sub-variety (*f*), Old Wiltshire.	Wiltshire	Southdown and Wiltshire.	short	fine	white	3 lb.	combing and carding.	
Sub-variety (*g*), Dorset.	Neighbourhood of Dorchester.	..	short	medium	white	3½ lb.	combing and carding.	Livery cloth at Ilminster.
Sub-variety (*h*), Cornish.	Cornwall	Cornish and Leicester.	long	coarse	white	6–7 lb.	combing and carding.	
Sub-variety (*i*), Old Lincoln.	Lincolnshire, Lincolnshire Wolds.	Lincoln and Leicester.	long	good	white	8–9 lb.	combing	
Sub-variety (*j*), Romney Marsh.	Kent	..	long	medium	..	7 lb.	combing	
	Southam, Notts..	Romney and Devon.						
Sub-variety (*k*), Bampton.	Devonshire, Buckland.	Bampton and Leicester.	long	very fine	white	8 lb.	combing	
Sub-variety (*l*), Exmoor, Notts.	Exmoor	Exmoor and Leicester.	long	medium	white	4 lb.	combing and carding.	
Sub-variety (*m*), Cotswold.	Devonshire ..	Cotswold and New Leicester.	long	medium	white	7–8 lb.	combing	
Sub-variety (*n*), New Leicester.	Dishley	..	very long	coarse	white	8–9 lb.	combing	
Sub-variety (*o*), Improved Teeswater.	Durham, York ..	Teeswater and New Leicester.	long	fine	..	9 lb.	combing	
Sub-variety (*p*), Woodland horned.	Lancashire ..	Leicester and Woodland, Southdown and Woodland.	..	..	..	..	..	This breed is nearly if not quite lost.
Sub-variety (*q*), Silverdale.	Lancashire.. ..	..	long	good	white	4½ lb.	combing	
Sub-variety (*r*), Penistone.	West Riding (Yorkshire).	Penistone and Leicester.	short	moderate	white	..	carding	
		Penistone and Cheviot.	short	moderate	white	..	carding	
Sub-variety (*s*), Isle of Man.	Manx Hills ..	..	short	fine	white and grey.	2½ lb.	carding	
	Manx Valleys ..	..	long	fine	..	7 lb.	combing	
Sub-variety (*t*), the higher Welsh Mountains.	The mountain sheep.	..	short	fine	white	2½ lb.	carding	Chiefly used for flannels.
Sub-variety (*u*), Soft - Woolled Welsh.	The Anglesea ..	..	medium	not very fine.	white	2½–5 lb.	combing and carding.	
Sub-variety (*v*), Cannock Heath or Sutton Coalfield.	Staffordshire ..	..	fair length	medium	white	6–7 lb.	combing	Though generally much discoloured by smoke, it washes quite white.
Sub-variety (*w*), Cheviot.	Northumberland	..	medium	medium	white	..	combing	
Sub-variety (*x*), Dunfaced.	Northumberland, Scotland.							
Sub-variety (*y*), Blackfaced.	Westmoreland, Cumberland, Northumberland, Scotland.	..	medium	coarse	white and grey.	..	combing and carding.	
Sub-variety (*z*), Hebridean.	The Hebrides ..	..	long	inferior	white	..	combing and carding.	
Sub-variety (*a a*), The Orkneys.	The Orkneys ..	..	long	not very fine.	white			
Sub-variety (*b b*), Shetland.	Shetland	..	..	the finest	white	1¾ lb.	carding	
	The Flounder-tailed.	Shetland and Dutch.	long	medium	white	4 lb.	combing	
Sub-variety (*c c*), Wicklow Mountains.	Cottagh	..	short	medium	white	2½ lb.	carding	Used for the flannels of Rathdrum, stuffs bombazines, bombazettes. The Irish breeds have been crossed with Leicesters, Southdowns, and Merinos in every country,
	The Irish	..	long	..	..	3 lb.	combing	

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
Sub-variety (*d d*), Herdwick.	Cumberland Hill.	..	short	very coarse	white	3 lb.	carding	Used only for low quality goods. This variety is remarkable for its hardiness and its peculiar sagacity in preparing for a coming snow-storm.
Sub-variety (*e e*), the Rass or Roosh.	Bokhara.							
3. Barwall Sheep (*Ovis Barual*, Hodgson).	Nepal.							
4. Hooniah Sheep.	Hooniah or black-faced sheep of Tibet.	..	long	soft and fine	..	..	combing	For ladies' dresses.
5. Cago (*Ovis Cagio*, Hodgson).	Cago or tame sheep of Cabul.	..	long	fine				
6. Seling (*Ovis Selingia*, Hodgson).	Nepal, central hilly region, and Eastern Tibet.	..	long	fine	some breeds black.	..	..	For rugs and coverlets.
7. Curumbar ..	Mysore	..	short	coarse	white, yellow, grey, brown, black.	..	carding	E. Indian wools are chiefly used for making blankets, small quantities also for carpets and rugs, and some of the longest for worsted manufactures.
8. Gārăr	India	..	short	coarse				
9. Dukhun	The Deccan ..	..	short	coarse				
10. West Indian	Jamaica	..	short	fine and soft, but mixed with hair.	..	..	carding	
11. Brazilian ..	South American, Pernambuco.							
12. Smooth-haired (*Ovis Ethiopia*, Charlet).	African	..	not used					
13. African (*Ovis Guineensis*, Rail).	Senegal and Sahara.	..	not used					
14. Guinea Sheep (*Ovis Ammon Guineensis*, Schreber).	The Guinea breed.	..	not used					
15. Morvant de la Chine.	China	..	short	rather coarse, but peculiarly soft and silky to the touch.	yellow	..	carding	Blankets, rugs, and carpets.
16. Shaymbliar	India, Mysore ..	..	not used	..	reddish brown.			
17. Zeyla	Zeyla and Mokha	..	..	..	white			
18. Fezzan.. ..	Tripoli and Tunis	..	medium long.	inferior fine.	white and grey.	..	carding	For making caps or fezzes.
19. Marocco (*Ovis Aries Numidæ*, H. Smith).	Marocco	..	short	inferior fine and soft	white and grey.	..	carding	Used for felt goods, blankets, and rugs.
20. Congo Sheep (*Ovis Aries congoensis*, H. Smith).	Congo	..	not used					
21. Angola Sheep (*Ovis Aries Angolensis*, H. Smith).	Angola	..	not used					
22. Yenu, or Goitered Sheep (*Ovis Aries Steatiniora*, H. Smith).	Angola	..	short	fine and close.	..	..	..	Not used in Europe.
23. Ixalus (*Ixalus probaton*, Ogilby).								
24. Cretan Sheep (*Ovis Strepsiceros*, Rail).	Crete	..	short and much curled.	soft and fine.	..	..	carding	
25. Long-tailed (*Ovis longicaudatus*, Brisson).	Russia, Odessa, Crimean.	Russian and Merino.	long	very soft	white			
	Wallachian.							
	Moldavian	..	long	superior, but mixed with hair.	white			
	Greek	..	short, curled.	fine				

TABLE OF THE VARIETIES OF FOREIGN AND BRITISH SHEEP—*continued.*

Varieties and Sub-varieties.	Breed.	Cross.	Staple of Fleece.	Quality.	General Colour.	Average Weight of Washed Fleece.	Combing or Carding.	General Application, &c.
25. Long-tailed—*continued.*	Barbary	..	hair not used.					
	Donskoi	..	medium	coarse	white and grey.	..	combing and carding.	
26. Broad-tailed (*Ovis laticaudatus,* Erxleben).	Odessa	Merino	short	very fine	white	..	carding	
Sub-variety (*a*), Fat-rumped Sheep (*Ovis stearopyga*).	Tartarian, Indian, Syrian, Chinese, Russian, and South African.	..	long	good				
Sub-variety (*b*), Persian.	Persian	..	long	medium	white, black, fawn, yellow, brown, grey.	..	combing	Used for nusmuds; the unyeaned lamb's skins for pelisses.
Sub-variety (*c*), Fat-tailed.								
Sub-variety (*d*), Aora fiyel.	Abyssinian.							
Sub-variety (*e*), Bokharan.	Bokharan, Caucasian, Persian, and Astrakhan.	..	short	fine and much curled, especially in young lambs.	black and grey in unborn lambs.	..	..	Much prized in the unyeaned state when the delicate grey curled skins are taken and dressed for furs, and the black for making the spots of minever and for wearing as fur.
Sub-variety (*f*), Tibetan.	Tibetan	..	long	soft and fine.	..	..	..	Used for dresses.
Sub-variety (*g*), Cape.	Cape of Good Hope.	..	fur-like, and used as such.	..	..	..	..	As fur for trimming dress, bags, &c.
Sub-variety (*h*), (*Ovis Aries appendiculata*).								
Sub-variety (*i*), Belkah.	Palestine and Plains of Belkah.	..	short	thick	white			
27. Many-horned Sheep (*Ovis polyceratus,* Linnæus).	India and Nepal, The Dumba.							
28. The Pucha ..	Hindostan, Dumba.	..	..	..	..	..	..	None of these is found in our market, according to Archer.
29. Short-tailed	Northern Russia	..	..	..	..	..	..	
30. Sheep of Tartary.	Tartary	..	..	..	..	..	..	
31. The Madagascar.	Madagascar ..	..	short	fine	..	..	..	
32. The Bearded	West African ..	..	hair not used.	..	..	..	..	
Javanese	Java	..	short and finely curled.	white	..	..	..	

This table, though not absolutely exhaustive, is sufficiently full to present in outline a fair view of the varieties of sheep, and the characteristics of many of their fleeces. It will be obvious that no hard and fast line can be drawn between the two classes or great divisions in wool, namely, clothing and combing wools. In the former, there are limits as regards length of staple in those suitable for the first class; for the latter, such requisites as soundness and elasticity. It will be clear, therefore, that within these conditions, are many varieties that will (within given limits) be fit for both uses. The qualities that should distinguish a high-class combing wool have been presented for enumeration as follows:—viz. (1) weight, (2) colour or lustre, (3) length, (4) freeness, (5) fineness, (6) elasticity, (7) softness, (8) soundness, (9) evenness of fleece. These points were submitted as queries to several wool dealers of the greatest experience, who were requested to divide a thousand points amongst them according to their respective values. Soundness and quality, not singly but combined, were reported by these gentlemen to constitute the most valuable attributes of a combing wool. The queries having reference to Australian wools, the estimation chiefly relates to merino wools from that country, in both combing and clothing descriptions. Following are the answers, tabulated according to the queries:—

Combing Wools.	Soundness.	Length.	Weight.	Softness.	Elasticity.	Evenness.	Fineness.	Density.	Lustre.	Total Points.
J. T. Symes and Co. ..	300	250	100	175	50	75	50	..	..	995
Hazard and Caldicot ..	170	170	150	80	90	80	50	60	..	850

Clothing Wools.	Length.	Density.	Softness.	Elasticity.	Evenness of Fleece.	Soundness.	Condition.	Weight.	Fineness.	Total Points.
J. T. Symes and Co. ..	..	150	200	100	100	50	..	100	300	1000
Hazard and Caldicot ..	50	140	80	170	80	80	140	150	..	890

In the preparation of wool for the market, it is desirable, if facilities permit, that sheep should be washed before shearing, because of the dirt and dust adhering to the yolk or grease of the wool. When this is retained, and the wool is packed and shipped in it for distant markets, it is apt to injure the colour, which cannot be restored. All such wool is disqualified for use in the production of fabrics intended to receive fine colours. In washing sheep, the yolk should be entirely cleared, and the sheep allowed two or three days' run, to permit the yolk to rise again to about 20 per cent. of the amount an unwashed fleece usually contains. This gives the wool a soft silky "handle," and maintains its natural elasticity and strength. After shearing, the fleece should be carefully skirted, and all locks, bellies, and stained, burry, and seedy pieces, removed; care ought also to be taken that shanks or kempy hairs are not folded in the fleece. When these parts are removed, the remainder of the fleece will be comparatively free from faults, and consequently all the more valuable.

Wools vary greatly in cleanliness, not only in the percentage of yolk or natural grease they contain, but also in the amount of foreign substances intermixed therewith. These consist of sand, dust, straws, burrs, and other matters, sometimes difficult of removal. The cleanest wools are those of this country; the next in order are those of Germany, France, Australia, Spain, Morocco, Algeria, Turkey, and Buenos Ayres.

Manufactured Wools.—During the past half century, a great branch has been added to the woollen manufacture, and is popularly called the "shoddy trade." Its development is characteristic of the time, which is conspicuous for its efforts to utilize bye and waste, or what were formerly called "waste," products. Many instances of successful results of this kind might be enumerated, but those that properly fall within the scope of this article will amply prove the economic tendency of the age. No sketch of the woollen manufactures would be complete if it omitted a notice of this recent addition to manufacturing industry. Busy centres of population and commerce have sprung up in Yorkshire, entirely based upon this trade, whilst the woollen industry throughout the country has received a great stimulus since shoddy became partly a competitor and partly an aid.

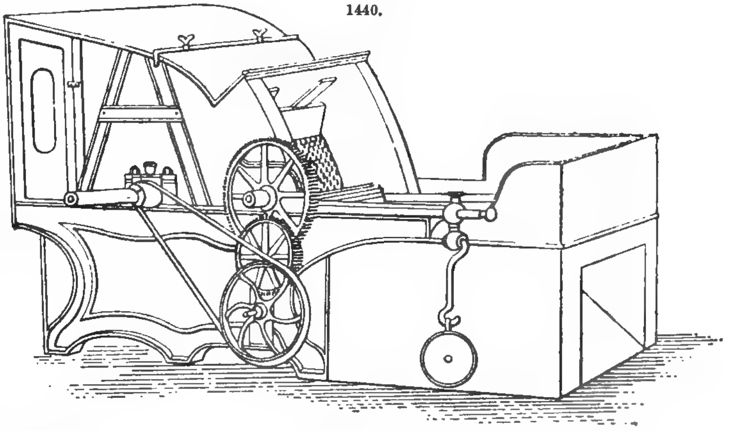
"Shoddy," in its widest sense, means all fibrous materials of animal origin that, having once undergone the processes of manufacture, are recovered from this state by destructive processes, having for their object the restoration of the fabrics to a fibrous condition. Of course, sheep's wool is the chief constituent of the textures so reduced, though fabrics in which the hair and wool of other animals is a principal or subordinate constituent are also included. These recovered wools are divided into three classes, distinguished by the kind of materials from which they are produced, or by the method of manufacture. The first of these is shoddy.

Shoddy.—This includes those recovered wools obtained by pulling into their original fibrous condition all descriptions of worsted and woollen fabrics known amongst dealers as "softs": that is, unmilled fabrics, such as old blankets, flannels, worn-out hosiery. It is difficult to decide to which amongst the several claimants to the invention of this system the credit is justly due. In Yorkshire, it is usually divided between, or rather claimed for, two persons, Benjamin Parr, of Batley, and Benjamin Law. An enthusiastic inquirer, who has devoted considerable time to the investigation, has, however, been led to the conclusion that the world is indebted to a Jew second-hand-clothes dealer in London, during the Peninsular War, when the stoppage of the supply of Spanish wool, and the brisk demand for army goods for the contemplated expedition to Spain (wool from Spain being then used for making them), drove wool to a great price. This man conceived that it would be a paying speculation to tear up old blankets and white flannels by curry-combs, and mix the product with the genuine wool that could be bought in the London market. This was done, and these "doctored" or adulterated bales were sold in Yorkshire for full prices, yielding a handsome profit to the operator. When this outlet for disposing of the product was closed by the decline in the value of wool, the maker offered it in competition with genuine wool for saddlery and upholstery purposes. This inventor's name is not satisfactorily known, but is conjectured to be Davis. The second progressive step in the utilization of this material (its adaptation to the manufacture of cloth) belongs to the above-named Benjamin Law, a small farmer and weaver of Batley, then an inconsiderable moorland village in Yorkshire. Not satisfied with the prices realized for his webs in Leeds, he extended his ventures to London. Being in the city on one occasion, he observed in a saddler's window some material apparently like white wool, but which differed in several respects from any with which he was acquainted. Getting permission to examine it, he found by testing its staple that it would fully answer his requirements. He found the manufacturer and purchased a parcel for himself, which he sent down to Batley, and fully satisfied himself that it was capable of being transformed into useful fabrics. He carefully guarded his secret, admitting only his brother-in-law, the Benjamin Parr before named, to a knowledge of his discovery. These two, having developed the manufacture to some extent, commenced to make the raw material themselves. From this small beginning, after struggling through many difficulties, its use has spread into almost every portion of the woollen manufacture of this and other countries.

Mungo.—The extensive adoption of shoddy as a raw material for cloth manufacture in a few years had the natural effect of rendering all the descriptions of rags from which it was manufactured considerably dearer, and of bringing the price of the product approximately near that of wool. To those who had experience of the originally low cost of both the rags and the product obtained from them, this change was not altogether of a satisfactory nature. There still remained open another source of supply, if only means of rendering it available could be discovered or invented. This was in the rags of milled cloths, both worn-out garments and new snippings from tailors' establishments. These were practically valueless, in most cases being thrown upon the manure heap, whilst from the London tailoring establishments the latter descriptions were obtained at a cost of about ⅛*d.* a lb., and were usually sold for the purpose of manuring the hop gardens in Kent and Surrey. After Law and Parr had been engaged in the manufacture of shoddy for about 10–12 years, they made an effort to utilize these "hard" rags, as they have since come to be called, as opposed to the "softs" previously described. New snips were procured from London, in order that, if successfully treated, the secret as before might be preserved. The first effort was, however, an entire failure, the machinery which was effectual for "softs" being quite unequal to the task of grinding "hards" into wool. Repeated trials were made, all ending in disappointment, the snips were thrown upon the manure heap, and afterwards carted away to the fields. The idea, though abandoned for the time, was not lost sight of. It is stated that it often occupied the thoughts of, and was the theme of frequent conversation between, Law and Parr. Some few years subsequent to the failure of the above trial, George Parr, a son of Benjamin Parr, observed at a neighbouring flock-manufacturers' workshop (Perrit & Co., Batley Carr), a description of flocks entirely new to him. Upon inquiry, he was informed that the firm were making a new kind of stuffing flocks by grinding up old coats. The young man saw that the grinding process was much more successfully accomplished than had been the case in their own efforts. Purchasing two bags, he sent them home, and made an effort to spin them, but found the cards of the Batley district too coarse for the necessary preliminary operations. Nothing daunted, he had them transported to Morley, to the establishment of John Watson, a manufacturer of fine broad-cloths. Here the efforts were renewed successfully, so far as the production of a thread was concerned; but it was pronounced to be quite useless, owing to the large admixture of cotton threads and linen linings that had been torn up with the cloth. Watson suggested that these should be picked out, and another trial made. This was done, and a more satisfactory result achieved, thought yet far from being such as would justify hopes of a commercial success. The trials were, however, continued by several manufacturers to whom the Parrs offered the materials freely. Successive improvements were made, but in spite of these, progress was slow. Finally the perseverance of the brothers Parr vanquished all difficulties. The article, called "mungo" from an ejaculation of one of the brothers that "it mun go," has since become an important source of supply of raw material to the union woollen manufacture, and to several other branches as well. Fig. 1440 is an illustration of the rag-grinding machine as at present constructed.

Carbonized Wool or "Extract."—A third class of fabrics containing wool yet remained to be utilized. This was composed of the union goods of Bradford and Norwich, in which, as a rule, the warp is of cotton and the weft of wool. The presence of the former in such intimate association made it impossible to utilize the latter to any commercial advantage. In the paper-making trade, the vegetable matter was successfully extracted from these rags by means of caustic alkali, which dissolved the animal fibre, leaving the warp intact. The reverse of this process was suggested by seeing the details of its operation in the Exhibition of 1851. A ship's captain named Corbett is stated to have been struck with the idea that it would be more advantageous to destroy the cheaper and preserve the more valuable fibre. To that end, he is alleged to have commenced the study of chemistry, and, after a while, found that a weak solution of sulphuric acid contained in a lead-lined vat, in which the rags were steeped for a short time, completely destroyed the cotton portion, whilst it inflicted little or no apparent damage on the wool. This soon led to the establishment of a manufactory for the production of extract wool on a commercial scale. The inventor found more difficulties in his way than he anticipated. It was looked coldly upon by the Yorkshire trade, who saw that the treatment to which it had been subjected had destroyed its felting properties, and rendered it extremely brittle. New outlets, however, were found for it, and a great demand sprung up amongst carriage builders, saddlers, and upholsterers. As a stuffing material, it was sold largely to the home trade, and was exported to the Continent and America. During the civil war in the latter country, there was an enormous demand for it for army and hospital purposes. In the meantime, the Germans had succeeded in adapting it to textile purposes. Such is one account of this invention. There are, however, numerous claimants for the credit of this discovery, and, as in other cases, in the multitude of assertions it is difficult to discriminate to whom the honour should be rightly awarded.

1440.



A claim has been put forward that "extracting" was first discovered and carried on for some time at Rochdale, the inventor in this instance carefully keeping his discovery as quiet as circumstances would permit. This was early in the decade 1850–60. Soon after, a Mr. Crone, of Manchester, suggested the idea to two men who were practically acquainted with the bleaching and finishing processes, as carried on around that town, and by them the process was again discovered, and patented. The original inventor, after some time, bought up this patent, in order to prevent disputes. When the matter became thoroughly known, numbers of people commenced using the process clandestinely, to the disadvantage of the owners of the patent. It is from amongst these that the crowd of claimants has arisen. "Extract" does not appear to have taken that important position in the woollen industries that has been awarded to shoddy and mungo, but it has had a considerable influence in diverting to itself a demand that would otherwise have continued upon the latter articles and pure wools. Its indirect importance, therefore, will be readily recognized.

From the finishing processes of the woollen trade, such as raising, cropping, &c., a considerable quantity of fibrous matter is obtained. These are called "croppings," "cuttings," "shorts," &c., and are the result of the shearing action of a machine employed to cut down the nap of the cloth after raising to a uniform level. This material also has been rendered available for the production of a very useful fabric, especially suited for the sharp winter temperature of such countries as New England, Canada, and Europe. This invention is of American origin, and consists in mixing "croppers'" dust in a strong solution of soap and size, in which a very loosely-woven fabric is then milled; this fabric takes up the short fibres, and can be worked up to any required weight or thickness, and afterwards be finished to a good surface. It is serviceable, durable, and cheap. An Englishman returning from the States is said to have brought back with him a knowledge of the process, which he introduced into Leeds. It has since spread into many other districts of Yorkshire, and other parts of the country where its raw material is plentiful, and has become a considerable industry. The demand for products of this kind outrunning the supply of croppers' dust, in 1873, Ferrar Fenton, of Batley, designed a machine for its artificial production from waste, since which, of course, the supply has been adequate to all requirements.

Processes of Woollen Manufacture.—Wool, in its transformation into woven fabrics, passes through the following processes, which, to save frequent repetition subsequently, are here briefly defined,

(1) "Stapling" or "sorting," which is the division of the fleece into its several qualities.

(2) "Opening" or "cleansing": freeing the wool from dust, sand, dirt, burrs, and foreign substances, and disentangling matted fibres.

(3) "Washing" and "scouring": two processes analogous in method and purpose. The former has for its object the removal from the wool of the dust and dirt adhering to the fibres after the latter operation; also the removal of that portion of the natural grease which, with the preceding matter, is soluble in water. Scouring is a succeeding process, in which the wool is passed through a solution of soap or alkalies and warm water, to remove the portion of the yolk uncleared by the foregoing process. The first is often omitted, and the second is followed by rinsing, the purpose of which is to clear the scouring solution from the wool.

(4) "Drying": to clear the wool from the water acquired in the preceding process.

(5) "Blending": the mixing of the different classes of wools and other fibres from which it is proposed to manufacture fabrics.

(6) "Oiling": lubrication of the wool fibres in order to render them workable.

(7) "Carding": the different stages of this process, scribbling, carding, and condensing, have one purpose, whether conducted with few or more machines, namely, to separate, straighten, cleanse, and mix the materials of the blend, in order to render the resulting yarn thoroughly homogeneous.

(8) "Spinning": woollen spinning performed on the mule.

These complete the processes up to the production of yarn, and now call for notice in detail.

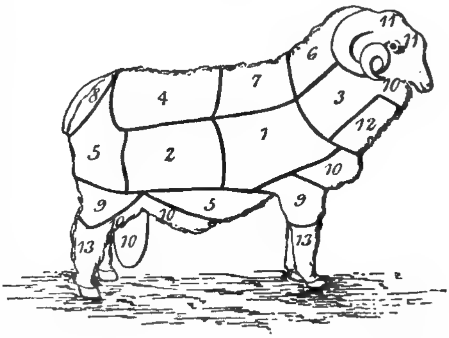
Stapling or Sorting.—Formerly stapling was a separate business, and the person following it was termed a "wool-stapler." This state yet prevails to some extent, but has not grown in a manner corresponding to the development of the woollen trade. In earlier days, the manufacturer resorted to the stapler for the supply of his raw materials. The stapler was a wool merchant, who purchased the wools from the growers, or from importing merchants, and sorted his purchases into various qualities, to suit the requirements of his customers, who thus by his aid were enabled to obtain exactly the quality of wool needed for their productions, without encumbering themselves with a large quantity of wool they could not use, as they must have done when they purchased the fleece from the growers. Thus the wool-stapler's function was a very useful one, and he himself was a highly-respected personage in the fraternity of the industry. But times have changed, and though not entirely superseded, his relative importance is greatly diminished. The increase of wealth, and the growing magnitude of manufacturing establishments have changed to a great extent the old method of business. The woollen or worsted manufacturer can now purchase his wool direct from either grower or importer, his consuming capacity and the variety of his productions enabling him to utilize all the qualities of wool obtained from the fleece.

The wool arrives at the stapler's warehouse or the mill in large bales, each containing about 400 lb. or 80–100 fleeces of wool. Having been weighed and compared with the invoices, the wool is ready for the sorter. Sorting is performed on an oblong bench, the framework of which is of wood, and the top of wirework grating, in order to permit the dust contained in the fleece to fall through. Most fleeces, however, hold a great quantity of dust, mostly composed of the dry epidermis of the sheep, which is so light as to rise and fill the atmosphere of the sorting-room, to the great detriment of the health of the workmen. In order to remedy this, the sorter's bench is now usually enclosed, and fitted with an exhaust fan, so as to prevent not only this light dust, but also much of the poisonous exhalations too often given off by the fleeces of foreign wools especially, from being breathed by the worker.

The sorter, taking a fleece, unrolls it upon his bench, and proceeds to separate it into the required qualities, depositing the different portions in baskets placed beside him for its reception. These baskets vary in number from 6 to 12, or sometimes more, according to the description of the fleece, or the requirements of the manufacturer. Short-wool fleeces, those consumed in the woollen trade, are usually distributed into ten parcels. The "picklock" is the highest quality obtained, and a fleece only yields a very small portion of this quality. The "prime" is the next best, and but slightly inferior to the preceding. Next follow the "choice" and the "super," both very good wools, but inferior to the previous selections. The bulk of the best fleeces are composed of these two classes. The succeeding division is termed the "head" wool, which probably indicates that it is the best of the second or inferior division of the fleece. The contents of the next basket are termed "downrights," a good useful wool, which is followed by the "seconds," the best of the wool from the throat and breast. The next is called the "abb," which is the eighth quality. The ninth is the "livery," and is composed of the skirtings and edgings; the tenth is the "short coarse" or "breech wool," that which comes from the breech of the animal.

These divisions are to some extent arbitrary, and differ according to the requirements of the manufacturer. Fig. 1441 shows the fleece divided into thirteen qualities:—Nos. 1 and 2, the shoulders and sides, always yield the best wool, being long, even, and soft, and the best grown wool of the fleece; the 3rd quality, that on both sides of the neck, is usually a little inferior to the preceding; the 4th, that on the loin and back, diminishes both in length and fineness from the preceding; the upper part of the hind legs yields the 5th quality, the wool in this locality beginning to hang considerably; the upper parts of the neck yield two qualities (6 and 7), both inferior in staple and occasionally faulty; at the root of the tail (8), the wool is more glossy, but coarse; No. 9 is the lower part of the leg, where the grease in the wool is dark in colour, and the staple is more twisted; on the throat (10), there is a great diminution of quality from that of some of the first numbers, the fineness, softness, and curl of the wool having nearly all disappeared, and "kemps" or hairs becoming frequent; the wool of the head (11) is coarse, often harsh, short, glossy, and sometimes dirty; on the lower part of the throat and chest (12), the yield is similar to No. 10, but often shorter, through friction against fences and bars; that from the shins (13) is short, glossy, and coarse, and nearly always very dirty.

1441.



In addition to these, which may be termed permanent qualities of the fleece, there are modifications that arise in flocks, or individuals, the result of differences in the quantity and quality of food and water accessible during growth; or are due to disease or a low condition from other causes. These will occasionally obliterate to a certain extent what may be called the permanent lines of qualities, the whole as a rule suffering degradation. When this occurs in an individual fleece, the sorter may be trusted to keep matters right by the manner in which he will distribute the parts, but when the parcel is faulty in these respects, it must of necessity be put aside for inferior purposes. The rapidity and skill which the sorter displays in the discrimination of the different qualities of a fleece, is a matter of astonishment to the cursory observer.

Washing and Scouring.—The cleansing processes of washing, scouring, and rinsing succeed the operation of sorting. Various methods of cleansing the wool are pursued in different countries, and in different circumstances. Sometimes the wool is first treated to a bath of cold or tepid clean water, for the purpose of removing all earthy matter, and the soluble portions of the yolk. This is succeeded by the scour, in which the wool undergoes a wash in a bath consisting of water heated to 49°–66° (120°–150° F.) or higher according to requirement. This dissolves the natural grease and suint, which form so large a percentage of the weight of the wool, and releases the remaining earthy matter adherent to the grease, and which had resisted the previous process of cleansing. In an examination of the merino fleece, Chevreul found that the raw wool of that breed of sheep consisted of:—Earthy matters, 26·06; suint, 32·74; grease, 8·57; earthy matter fixed by the grease, 1·40; clean wool, 31·23. The proportion of clean wool yielded by other descriptions varies from 25 to 40 per cent., and sometimes rather more; but as a rule, it may be accepted that the processes of washing and scouring will reduce the raw weight by about two-thirds. It is obvious that the removal of this large proportion of the weight will require to be performed with care, in order not to injure the clean fibre, by making it hard or harsh, or causing it to shrink, and thereby injuring its felting properties. This care must be exercised in the selection of the most suitable detergent for forming the scouring bath, the preservation of a proper temperature during the passage of the wool, and the prevention of too sudden a transition from the warm scour bath to the cold rinsing or clearing bath, should cold water instead of tepid be employed in the latter.

Formerly, stale urine was in much request for scouring purposes, for which it was found very suitable, owing to the presence therein of a considerable quantity of carbonate of ammonia, which is a weak alkali, whilst the accompanying organic matters were also useful in protecting the fibre from the action of the stronger alkalies added to the bath. Its insufficient supply, combined with its offensive odour, has greatly diminished its use. Ammonia is also frequently used for the "scour," and that obtained from urine is the best for the purpose. Gas-liquor yields a considerable quantity of ammonia by distillation, but when obtained from this source, it is apt to contain hydrocarbons and sulphide of ammonium, the former of which are injurious to the hands and skin of the workpeople, and the latter damages the wool. Carbonate of soda is another scouring agent, and, in one form or another, is very extensively employed. It is an ingredient, and often the chief one in the special preparations or compounds, retailed in the woollen districts as efficacious wool purifiers. (See pp. 1788–9). Soaps are the most generally accepted scouring agents. In order, however, to employ them so as to secure a satisfactory result, it is imperatively necessary to obtain them of uniform strength. Few articles are more liable to adulteration than soap, as few better hide the sophistication.

Silicate of soda, or soluble glass, has of late years been extensively introduced as a detergent for cleansing wool, and it is stated to have been found to possess valuable properties. Like soap, it holds its alkali in feeble combination. Its detergent power is considerable, and it may be employed alone or in combination with ordinary soap. When used alone for scouring wool, the latter should be well pressed to clear it thoroughly, otherwise the silicate is apt to coat the fibres with a thin film when it comes into contact with the cold water in which the rinsing is performed. Should this occur, dyeing or bleaching of the wool afterwards will be impeded, and the wool rendered more harsh than when properly cleared.

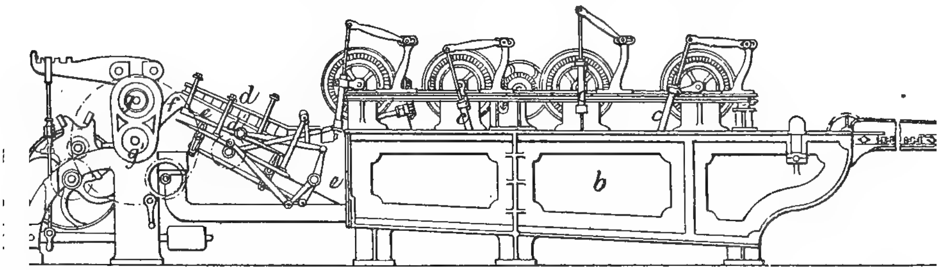
In using soap for scouring purposes, in conjunction with an alkali, soda crystals is the best form if a carbonated alkali is used. A small quantity of powdered double-refined caustic soda, however, can be substituted with advantage in most processes; as compared with soda crystals, not exceeding $\frac{1}{10}$–$\frac{1}{5}$ part of the quantity of soda ash usually employed. It is absolutely necessary that the caustic soda should be free from iron, and that it should be moderately used.

Wool washing is performed by very different methods in different countries. In some, clear running streams are utilized; in others, mill-streams for turning water-wheels, either before or after passing the latter. In other cases, tanks, tubs, or any vessel capable of holding water, are made to do duty for this purpose. A common way, and that perhaps most generally in vogue, is to scour wool in a round tub provided with a false bottom of either wood or galvanized wire. This bottom is usually placed about 9–12 in. from the true bottom, so as to form a cavity for the reception of the sand, dirt, and other matter that the washing releases. The perforations of the wooden bottom or the spaces between the wires are so arranged that, whilst permitting the sediment to pass freely through, the wool is prevented from going at the same time. This bottom is supported upon vertical strips of wood, and is furnished with handles to facilitate lifting it out of the tub when required, in order to cleanse the bottom. The tub is generally about 5 ft. deep and 4–5 ft. diam. The water is heated by means of steam, delivered by a pipe going down the inside of the tub to about 3 in. below the false bottom, and which is furnished with a tap to turn off the steam when a proper temperature has been attained. On the top, and projecting to the outer side so as to form a slope, is affixed a frame having vertical sides about 6 in. high, across which narrow strips of wood may be nailed, or a sheet of galvanized wire extended, to form a strainer or "scray;" upon this the wool is placed to drain after being lifted from the wash, and previously to rinsing in clear water. "Squeezers," or a pair of pressing-rollers usually intervene between the "scray" and the "rinsing-box," but not always. The latter vessel is mostly an oblong box about 5 ft. deep, having also a perforated copper bottom, the holes of which are about $\frac{1}{16}$ in. diam., and as numerous as the strength of the sheet of copper will permit. A copious supply of clean water is required for this vessel, in which, having received its contents, the wool from the scray is immersed and agitated, or passed backwards and forwards by means of a wooden fork, until thoroughly cleansed from the "scour" or suds of the previous bath, and the grease and suint that it has liberated.

The process is to carefully prepare the scouring bath, caution being observed to get it to the proper temperature, for ascertaining which a thermometer should be used. The wool is then placed in the bath in such quantity (but not more than that) as will allow it to be freely agitated, so that every fibre may be fully exposed to the action of the bath. The agitation must be performed in such a manner as not to render the wool stringy, but to keep the mass light and open. The same procedure must be followed and the same care displayed in the rinsing process. If the operation has been properly performed, the wool will leave it in a soft and open condition. Tepid water is always best for the rinsing process, helping considerably to attain the desired ends. By this method, 500–1000 lb. can be washed per diem in one tub.

During the past 20 years, however, much has been done in this country in introducing machinery for the washing of wool. Since its invention, it has moved steadily towards perfection. This has caused it to rise rapidly in public estimation, and, as a consequence, to get generally adopted. There are several makers of wool-washing machines, whose productions leave little to be desired or even accomplished in the way of perfectly performing their work. Fig. 1442 shows one of the best, by J. and W. McNaught of Rochdale, and embodies the latest improvements. The single 4-rake machine here shown occupies a floor space of 24 ft. 9 in. in length by 6 ft. 8 in.

1442.



greatest width over the pulleys. The feed *a* is a travelling apron, upon which the wool to be washed is evenly spread by the attendant, and in that manner passes into the tank *b*, where it is immersed in the prepared bath, and brought within the action of the first rake. The series of rakes *c* are actuated by the bevelled gearing shown, which carries cranks, whose revolutions immerse the rakes at the point of their traverse nearest the back or feed end of the machine, and slowly push them through the liquid, each rake carrying with it the wool that had come within its reach, and delivering it to the next. This slow propulsion prevents the matting or stringing of the fibres, and the felting that would ensue were the action quicker, whilst it is sufficiently quick to thoroughly cleanse the wool by the time it reaches the opposite end of the tank. Here the last rake delivers the wool to the reciprocating harrows *d*. These are frames with rows of alternate prongs on the under side. Each frame moves with its prongs parallel to and nearly touching the inclined plane, and returns over it with its prongs away from and clear of it, in the same manner as the rakes of the tanks retire backwards over the water. The inclined plane is made of polished plate-glass, in order to reduce the friction to a minimum, and consequently the stringing and entanglement of the fibre, whilst the rapid flow backwards of the water brought with it by the saturated wool returns all impurities that might have been brought up therewith into the tank. As one harrow is travelling up the plane with the wool it has received, the other is returning. The washed wool is brought forward by the strokes of the rakes to the bottom of the incline, upon which it subsides within reach of the harrow, which then slides it up. Arriving at the top, it descends by its own gravity, a chute or reverse incline *f*, also of plate-glass, at the bottom of which it comes within the action of the pressure-rollers *g g′*. The prongs of either one or other of the harrows are always acting upon the wool, sliding it forward over the plate-glass surface, neither leaving it until the other has descended upon it, which produces a constant and uniform delivery, preventing all backward slip, which would lead to entanglement.

These machines are easily combined, and made single, double, triple, or sometimes in sets of four. In small establishments, a single machine may suffice, the wool being put through twice; the first time for scouring, the second for rinsing. In large establishments, where a great quantity of wool is consumed, and the best results are desired, the combined machines are used, and the wool is washed, scoured, and rinsed at one operation. In a set of four, cold or tepid water may be used in the first trough, scouring baths in the next two, and again tepid or cold water as may be desired in the last; or any other arrangement may be adopted that skill and experience may devise as likely to yield the most satisfactory result. When the liquor in the first scouring-trough has become unclean, it may be run off, and that from the second made to take its place. For this purpose, the makers have invented a steam-jet transmittor, which causes the liquor when required to flow quickly from one trough to another, thus enabling all the troughs to be placed on one level, instead of at different elevations, as necessitated when the contents are required to flow from one to another by gravitation. The steam used for this purpose is utilized in warming the respective baths. Where it is impossible to arrange several machines in a straight line, the troughs can be made in the form of an elbow, the feeder being at right angles with the delivery.

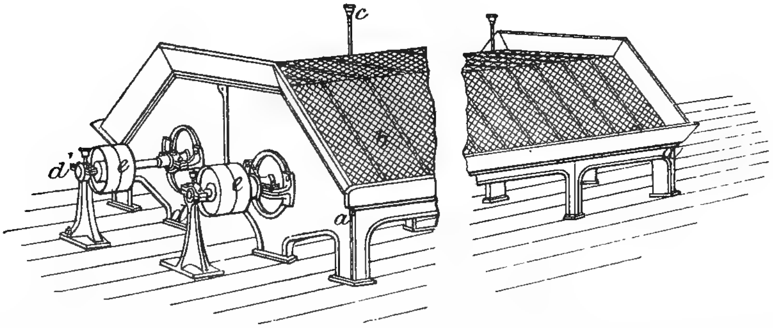
The process of cleansing the raw material is exceedingly important, and when badly performed gives rise to the most unsatisfactory results, the real cause of which frequently passes undiscovered. To secure the end sought, requires the employment of soap uniform in strength, the use of a proper quantity for each bath, the right temperature of the water, care in rinsing, and uniformity in feeding. On no account should the troughs be so filled with wool as to cause the latter to be shovelled forward, as it were, by the rakes; but the supply should be so graduated as to allow each lock to be thoroughly exposed to the cleansing influence of the scouring liquor, and similarly to the clearing action of the rinsing bath at the close. These points require conscientious attendance.

Drying.—Wool which is intended to be dyed passes from the scouring to the dye bath. When this is not the case, it is dried.

The process of drying, as usually performed, is in several respects unsatisfactory. Ordinarily it is spread upon a perforated iron floor over the boilers, when that can be arranged, in order to economize what would otherwise be wasted heat. When this is not convenient, steam-pipes are arranged so as to admit of the wool being laid over them. Layers of wool are then spread over the area in succession, and the wool is dried by exposure in this manner to the radiant heat. It is obvious, however, that when the layer is unevenly spread, which cannot be avoided, the drying will be uneven, and injury to the wool will result. The parts in contact with the floor will dry first, and, if not very carefully tended, will become hard and brittle before the other or upper portion of the layer has been sufficiently dried. The manner in which this is sought to be obviated is by turning the wool frequently and respreading the layer. If carefully done, this prevents much injury accruing, though the evil is not entirely eliminated.

This process, unpromising as it might appear, has also been subordinated to mechanical treatment, and Fig. 1443 represents one of the machines employed for this purpose. As will be seen, it consists of an oblong iron frame *a*, with sloping sides and a flat top. A light iron frame, over which is stretched a covering of strong galvanized iron network *b*, forms the roof. Above this project a number of tubes *c*, forming air-inlets, which are arranged at equal distances from each other in two rows. Two shafts *d d'* extend horizontally through the length of the frame, having bearings or journals of special construction, which are self-lubricating. These journals are placed immediately above each air-inlet. On each shaft, is a series of fans, composed of wrought-iron, and having similar casings or bottoms. These fans draw the air in through the inlets *c*. Inside, are a number of steam-pipes, made of either wrought or cast iron, 2–3 in. internal diameter. The fan-shafts carry fast and loose pulleys *e* for driving.

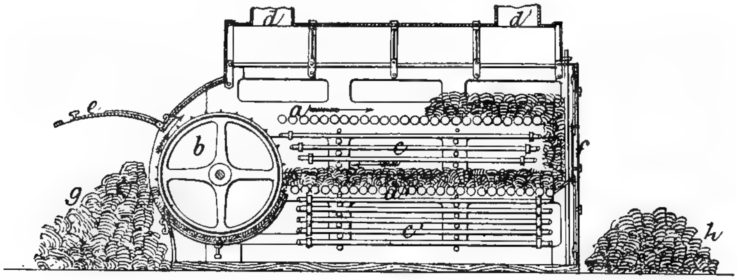
1443.



The process is as follows:—The net-work being covered with a uniform layer of wool, not very thick, the steam is turned into the pipes, and the fans are set to work. These draw the air through the inlets; in its course it comes into contact with the steam-heated pipes, by which it is warmed, and then uniformly discharged through the net-work and the layer of wool. As the heat can be regulated to a nicety, or even cold air be employed, the wool with care never need be overdried or rendered harsh. This machine is also made by McNaught. Its dimensions are 6–9 yd. by 3 yd. It is capable of drying 2000–3000 lb. in a day of 10 hours.

The objections to the antiquated system of drying described above, have also led to the invention of another drying-machine, a longitudinal section of which is shown in Fig. 1444. This differs essentially from the one just described. It is the invention of Moore, of Trowbridge, the centre of the West of England clothing district, and is made by W. Whiteley and Sons, Lockwood, near Huddersfield. Hot air is the agent employed in drying, as in the preceding machine, but provision is made for continually redistributing the wool. The moving parts, omitting cognizance of the driving-gear, consist of two series of rollers *a a'*, and a drum *b* about 4 ft. diam., the periphery of which is covered with small spikes. When working, this drum makes 100–120 rev. a minute. The two series of rollers also revolve, though only at a slow pace, their function being to carry the wool backwards and forwards. As the rollers of each series all revolve in one direction, it is obvious that the wool will be passed from one to another until the end is attained. The rollers are made of iron tubes of about $3\frac{1}{2}$ in. diam., and are set sufficiently far apart to allow of free revolution, the interspaces permitting the circulation of the current of heated air. The revolution speeds of these rollers can be regulated according to requirement. Beneath the rollers, are several tiers of steam-pipes *c c'*, for the purpose of heating the air. At the top of the machine, are two flues or tubes *d d'*, whose extremities are carried outside the building, and are supplied with power-driven exhaust fans, for the purpose of inducing a current through the machine. Each end of the machine is furnished with

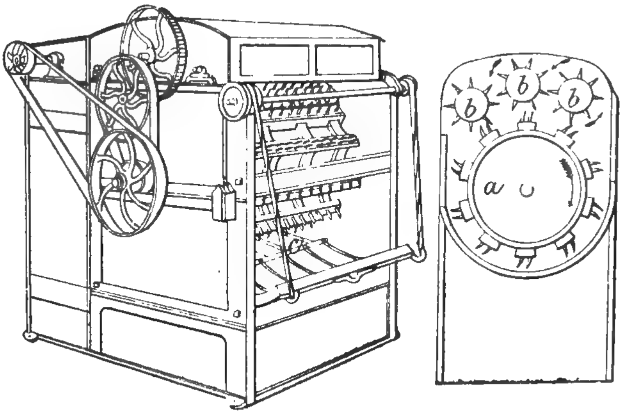
1444.



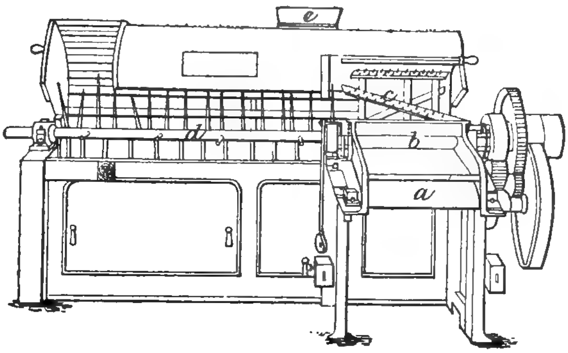
a door. When the process commences, the door *e* over the spiked drum is closed and fastened, and the one at the opposite end *f* is opened for the reception of the charge of wool. The weight usually put in at one time is sufficient to yield about 100 lb. of dry wool. This quantity is placed upon the lower series of rollers, and the door is then closed. By the action of the rollers, the wool is gradually carried forward, until it comes within reach of the spikes of the revolving cylinder, which strike it downward, carry it round, and project it upon the upper series of rollers. Here it commences its return course, and when arrived at the last roller, it falls over, dropping down upon the lower series again, when it recommences and repeats its journey. This is continued for 20–30 minutes, when the charge will be thoroughly dried, and ready for withdrawing. The door being opened, the spiked drum throws out the wool *g*, as shown in the illustration. The heap *h* represents wet wool. The traversing of the wool by the rollers, and its teazing by the spiked cylinder, secures thoroughly uniform drying, whilst the action of the latter also often renders it unnecessary to pass the wool through a teazer before sending it to the card. To facilitate the extraction of dust, dirt, and foreign matter, a grid is inserted in the under portion of the case. About 1500–2000 lb. of wool may be dried upon the machine represented. It is made in various sizes, according to requirement.

Opening.—After being properly dried, the wool is ready for opening, which has for its objects the disentangling of any matted fibres, rendering the whole mass loose and open, so that the fibres can be easily worked or drawn from each other in subsequent stages; and the removal of the dust and impurities that remain after the washing and scouring processes. The "shake willow" or "teazer," Fig. 1445, is the machine usually employed. It is composed of a cylinder *a* having spiked teeth, which usually runs 400–500 rev. a minute. Over the cylinder, workers *b* are arranged, which are actuated by means of the gearing shown on the exterior. These make about 30 rev. a minute. The action of cylinder and workers in combination tears and opens all matted and entangled portions, and releases the dust and foreign substances, permitting the heavier portion to fall through the grid *c* at the bottom. At the back, an exhaust-fan having a rapid revolution draws away the lighter refuse, which is discharged through a tube into the open air. The machine receives its charge through the door formed by the grate, which, being hinged, can be raised or lowered at will. When closed for work, a canvas apron is brought down before it, to confine the dust. When charging, the attendant takes up an armful of wool, and placing it in the machine, closes the door, sets it to work, and allows it to run for the time which experience teaches him the quality or state of the wool will require in order to effect a thorough cleansing. After work has commenced, it is usually charged and fed without being stopped, though the operation is not free from risk, and a little carelessness renders it highly dangerous.

1445.



1446.



Of late years, efforts have been made to improve the common "willow." Fig. 1446 shows one of the most recent attempts to realize this end. In some respects, it is not unlike the conical willow, so well known in the woollen trade, and which was adapted originally from the cotton trade; but it has several important differences. The wool is placed upon the endless apron *a*, by which it is carried to the feed-rollers *b*; behind these, it is immediately seized by the teeth *c* of the teazer, which tear it asunder and open it out. These teeth are set upon bands of iron, arranged spirally round the front part of the shaft, in such a manner as to send the wool forward towards the interior of the machine. This part is constructed so as to form a fan, which, by its action, draws the air forward, and with it the wool, preventing the latter becoming matted or entangled. When the wool has cleared these teeth, it enters the larger part of the machine, where it comes into contact with the beaters, helically arranged upon the shaft *d*. These, whilst the wool is suspended in the air, drive it against the casing of the machine. This casing in the upper part is provided with iron rails, against which the wool is thrown, and further opened without injury. The lower half of the casing consists of a grid, through which the dust and dirt escape. The fore part of the grid, beneath the teazer, is composed of iron bars, whilst that of the length under the beater is of wire network. In the former case, the heavy dust and dirt of dyed wool is shaken out before it comes to the blend, where it would absorb a large quantity of oil. When the wool has arrived at the end of the machine, it is ejected through an opening provided for that purpose. One important addition is the hopper *e* on the top of the case, which will permit the introduction a second time of wool that requires an extra amount of beating, but which might be injured by further teazing, the teazer being avoided at this point. It also serves for introducing wool of a quality that requires no teazing. Mungo and wool may be mixed by the same means. The novel points embodied in this machine entitle it to the notice of manufacturers.

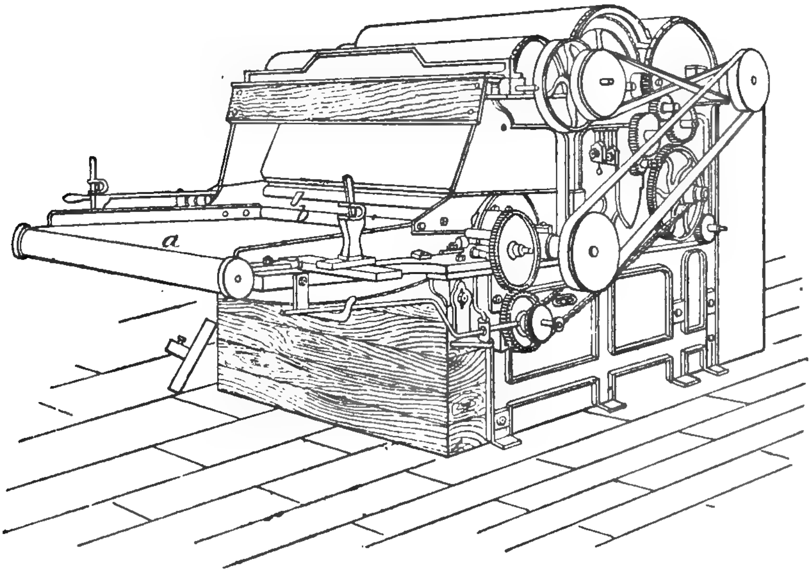
Burring.—Many wools contain a great quantity of seeds, and other matters of vegetable origin, acquired in the pastures in which the sheep have been fed. These are technically termed "burrs," and are often exceedingly difficult to remove, owing to their frequently being covered with sharp hooked prickles or claws, a provision of nature to effect their distribution. These considerably depreciate the value of wool, because of the trouble and cost entailed in their removal. If allowed to pass on to the card, they get broken up, the husks and spines becoming embedded in the yarns and cloth, occasioning much annoyance in the spinning and weaving processes, and ultimately being discoverable in the finished fabric, yielding a sensation as if the manufacturer had wrought into his cloth an infinite number of needle points.

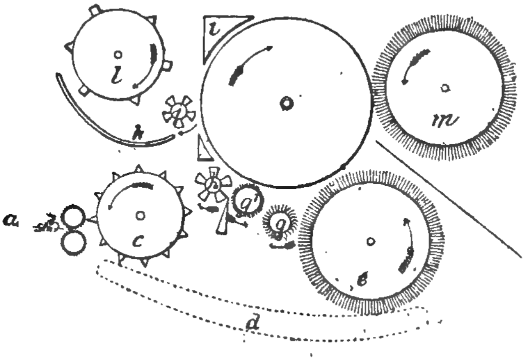
There are two systems of getting rid of this vegetable matter, both of which are effective and highly useful, though not without certain drawbacks. The first is by means of the burring-machine, and the second is by the process previously described as "extracting," by which, in the rags of union textures, the vegetable matter is destroyed, leaving the wool or other animal tissues intact for use again. The extracting process is deemed the best for the class of wools and noils technically denominated "shivey," and which contain broken burrs, small seeds, and motes in considerable quantity, for the removal of which, the burring-machine would not be very efficacious. To some extent, the nature of the wool is injuriously affected by the chemicals used, but this is a minor evil compared with the other, and therefore is the one the manufacturer elects to encounter. Where the "burrs" are of fair size and unbroken, it is preferable to remove them by mechanical means, rather than by the chemical process. The wool is thereby preserved in all its qualities, at the cost of a little trouble and expense.

The burring-machine is represented in perspective and section in Figs. 1447, 1448. It has the usual feed-lattice *a* and rollers *b*, after which comes a beater or fan *c*. Underneath the working parts, a travelling lattice *d* is extended; over its further extremity and in contact therewith, is a roller-brush *e*. The latter works in contact with the large cylinder, which is fitted with a series of steel plates, about 1 in. in width, set closely together, the front edges of which are armed with fine steel needle-like teeth, inserted obliquely, so as to incline the points upward or forward in the direction of the revolution of the cylinder. These teeth do not project above the surface. Beneath the cylinder, are two small rollers *g g'*, the first being clothed with bent card wire, and the second with strong hog-bristles. In close proximity to *g'*, is the burr-roller *h*. Just above the burr-roller, two bars of iron *i* are extended across the face of the cylinder, the sides against the cylinder being concave. These are termed "ledger-blades." Acting in the space between these blades, is another burr-roller *j*, and beneath this is a grid *k*, over it being another large roller *l*, carrying ribs and spikes. On the opposite side of the cylinder, is another large roller-brush *m*, whose function is to strip the wool from the cylinder, and discharge it into a box.

The process is as follows. The wool is fed by hand upon the lattice *a*, which carries it between the rollers *b*, on delivery from which, it is struck downwards in tufts by the beater *c*, falling upon the interior lattice *d*, which carries it into contact with the revolving brush *e*; this conveys it to the cylinder *f*, the needle-pointed armour of which seizes the fibres, but forces the burrs into a prominent position, which subjects them to the strokes of the spiral blades of the burr-roller *h*, sometimes called the "knocker-off." The small card-roller *g* strips the wool from the brush-roller *e*, which happens to escape being taken in the first instance by the large cylinder. This it delivers to the brush-roller *g'*, which in turn gives it to the cylinder. When the wool has passed the burr-roller *h*, it is smoothed down by the concave faces of the bars *i*, after passing the first of which, the burrs that have escaped the first roller are caught by the second *j*, and struck off upon the grid *k*, where they become subject to the action of the large roller *l*, whose function is to beat them through the grid into a receptacle provided for them. The wool now freed from its impurities is carried forward by the cylinder to the brush *m*, which revolving at a greater speed than the cylinder, clears it, and discharges the wool into a box.

1447.





1448.

The principle of the machine is to open and disentangle the fibres of the wool so thoroughly as to loosen and throw the burrs into a position where they can easily be struck off and discharged by the rollers. The wool that adheres to the burrs can be recovered by the "extracting" process.

Blending.—The wool having got thus far is now ready for "blending." This is the mixing of different qualities together, in order to produce the required result. Where only one kind of wool is used in the process, it is simply spread in layers, and freely sprinkled with oil, when it is considered desirable to oil at this point. "Blends," however, are often made up containing more or less of other fibres than wools strictly so-called. These are analogous animal hairs, shoddies, mungoes, "extracts," cotton, and silk waste. Of whatever the blend is composed, care should be taken to ensure that it shall be so thoroughly mixed that, in the succeeding processes, the incorporation of one fibre with the other shall be so perfect that all distinction between them shall be lost. If this is not accomplished, the yarn will exhibit inequalities of draft, owing to the essentially different nature of the fibres, showing a mass of cotton or other fibre at one place, and wool almost alone at another. In the dyeing and finishing processes, these defects come more strongly into view, after having at each stage proved unsatisfactory in working, and diminished the production. When the blend is composed of both animal and vegetable fibres, this care is doubly necessary, otherwise each fibre is likely to assert the individuality of its nature, and to separate from that with which it was required to blend. To ensure the desired results from the mixtures of fibres differing so essentially as do those of animal and vegetable origin, the amalgamation must be perfect.

In deciding upon the component parts of a blend, regard must be had to the fact that these different fibres do not all require a similar amount of carding, and that an incongruous mixture in this respect will often prevent the attainment of satisfactory results, even when otherwise the most perfect care has been displayed. When two classes of material are required to be mixed, they should harmonize in this respect as much as possible, which will give a chance of obtaining, if not of securing, the production of approximately perfect yarn. Another point to which attention ought to be paid is the fineness to which it is intended to spin the yarn. The capability of the separate fibrous materials of being drawn to this length must be kept in view, and harmony as nearly as possible be established, otherwise the capability of the best portion will be lost in that of the inferior; or if the former is utilized, the lower quality will be thrown out as waste, and the result be costly and unsatisfactory. The end to be sought is to obtain the greatest possible percentage of yarn from the blend, at the least expense in labour; this cannot be done unless regard is had to these points. It is not true economy to overwork a low material, nor to underwork a good one. One fault is equally as bad as the other, though the errors may be on the opposite sides of the line of rectitude.

In blends of different qualities of wools, or of wools and other fibres, one general principle should always guide the proceedings. This should be to spread out a thin layer of one quality on a clean floor over as wide an area as convenience will permit, upon which all the successive layers should be placed equally thinly, and in proper rotation. The batch should be well beaten down with sticks, which will help to blend the materials, and keep the bulk within reasonable compass. When used, the material should be always taken from the sides: drawn down vertically from top to bottom by means of a short-pronged rake. This will secure a thorough intermixture of the mass. To take from the top, it will be obvious would simply be to separate the materials again.

Wool and Silk Waste.—In laying down a blend of wool and silk waste, it is important to see that the silk is cleared from the natural gum, as otherwise it will not easily intermix, and in after processes could with difficulty be retained. Should it afterwards be subjected to warmth and moisture, it is also liable to have its gum partially dissolved, which would cause it to adhere to other portions, and to clog the machinery in an inconvenient manner. The next point of importance is that the silk waste must be of the colour intended for the ground of the fabric, and not that of the relieving mixtures. Should it be intended to produce a gray mixture of say 75 per cent. black and 25 per cent. white, the silk waste must form a portion of the black. The wool before the admixture takes place should always be thoroughly well scoured. The silk waste should be reduced in the fibres as nearly as possible to the length of staple of the wool with which it has to be mixed. The fineness should also approximate as closely as can be attained. The silk portion of the blend being extremely light, it is requisite to have all parts of the carding machinery—cylinders, workers, doffers, and "fancy"—very accurately adjusted, and the clothing smooth and sharp. The doffers should not exceed about 4 rev. a minute, and the "fancy" ought only barely to exceed the rate of the cylinder, so as to work with as little draught as possible, in order to prevent the generation of electricity. Oleine is the best lubricant for this blend, but care must be taken to have it free from acid.

Wool and Cotton.—Blends of wool and cotton are usually for hosiery purposes. In this class of mixtures, the Belgian manufacturers have achieved considerable eminence. With their system, they have successfully mixed all proportions of wool and cotton, reducing the former element until it has become conspicuous mainly by its absence. In each case they have produced useful yarns—at a price with which other spinners and manufacturers have found it difficult to compete. The poorer qualities of course are devoted to the production of low grades of yarns. These have usually been known as "Vigogne" yarns, so called from a Brazilian animal whose fleece partakes of the characters of those of the sheep and the goat.

A high quality of this yarn would be composed of half wool and half cotton. Both materials should be good and sound in staple. The wool ought to be fine merino, and the cotton of long staple and very clean. The wool should be thoroughly cleansed from dust and foreign substances, well scoured, carefully dried, willowed, and oiled. The carding process requires to be carefully performed, the ordinary breaker-card being usually selected. All the parts should be accurately adjusted, the workers put on slow speed, and the clothing perfectly smooth and possessing a good working point, so that the wool on being put through shall be delivered as straight as possible. It should be made into a lap in this process.

The cotton is first put through the opener, and made into a lap. For good work, it is then carded to take out all short or defective fibre, neps, motes, &c., in order to secure a clear yarn. Where this is not essential, the carding may be dispensed with. After carding, the slivers are again put through the opener to facilitate admixture with the wool. The proportions of each are next weighed out, blended together, and again put through the teazer once or twice in order to secure thorough admixture. The slivers are then ready to go through the woollen card and condensor. The result, if the operations are properly performed, will be a clean, level, and thoroughly uniform yarn.

Where the highest results are not wanted, a simpler method is often adopted. The proportions being decided on, and weighed out, the wool is first teazed, then oiled, then teazed again. The cotton is next put through the opener, after which the materials are carefully mixed, each layer being spread out very thinly one over the other until the blend is completed, when the mixed material is taken from the side, and again passed once or twice through the teazer, care being taken each time to further blend the material, when it is brought from the front to the back of the machine, by turning the outside of the mass to or upon the middle, there being a tendency (owing to difference of specific gravity of the two fibres) to separate. The cotton must in no case be oiled, as it will take from the wool all the oil it will require.

Oiling.—The oiling of wool is an important and indispensable process in the manufacture of woollen thread. Its purpose is to cover the scales of the fibre, and make a perfectly even surface, which will allow the fibres to glide over each other without interlocking, and without injury to the scales, in the processes through which the wool has to pass. Insufficiently oiled wool loses much more fibre in its manipulation, and suffers injury to its felting property, thus yielding an inferior article at a higher cost, compared with that obtained from a properly lubricated stock.

The plan of oiling in most general use is the hand process. This is best performed in the following manner. The blend having been properly made, and mixed in the teazer or "fearnought," a portion, say as much as can be conveniently used before considerable evaporation ensues, should be taken and spread over as large an area as convenience will admit of near the back or feed of the machine. The spreading should be in thin and even layers. Each layer in succession should be liberally oiled, and at every second layer the mass should be beaten down with sticks, which serves to bring all the fibres into contact with each other, and so to distribute and ensure a thorough oiling of each. The best instrument for securing an even distribution of the oil is a can having a spout in the form of the letter T, both stem and crosspiece being tubes, the latter perforated with several rows of fine holes, whilst its ends are closed with caps which can be taken off for cleaning. The tubes should be about 1½ in. diam., and the cross-piece 9 in. long. The oil should be strained or filtered through a piece of thin cotton cloth or other material that would take out coarse impurities. When this has been done, the oil-can, being supplied, should be swung backward and forward over the layer of wool, in such a manner as to carefully and evenly distribute the oil, and secure the oiling of every particle. Each layer should thus be oiled in succession, until the whole is completed. When used, the wool, as before, should always be taken from the side of the blend, commencing at the top and drawing downwards. All points considered, this system of oiling gives the most satisfactory results. There are, however, several plans of mechanical oiling, means for accomplishing which are attached to the teazer, fearnought, or carding-engine.

In oiling at the teazer or fearnought, a revolving brush is generally used, which is so arranged as, after taking up oil from a tank, to cast a fine spray of oil amongst the material just before entering the machine. When this system is adopted, it is desirable to again pass the wool through the fearnought, to secure thorough lubrication of each fibre.

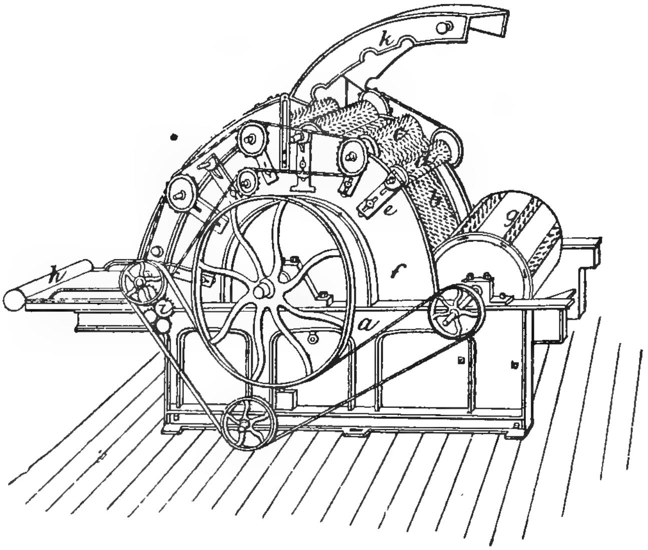
Wool is sometimes also oiled just previously to entering the carding-engine. It is accomplished by a mechanical appliance, similar to that just described. Advantages are claimed for this system over both the preceding, and in theory it is perhaps superior, and affords a better opportunity than either of the others for effecting thorough lubrication. The practical difficulties, however, have hardly been fully overcome. The system is therefore not yet likely to supersede the first-named.

An important matter requiring the careful consideration of manufacturers is the kind and quality of oil to be used in this operation. The object of oiling, as previously stated, is to cover or sheath the scales on the surface of the wool so as, in the first instance, to prevent their becoming entangled with each other in the working process, which leads to great waste of its fibre and damage to that which is not lost, whereby it is injured in its felting properties; in the second, it is to preserve the latter quality intact for utilization in the fulling process. It will be obvious that other fluids would serve equally well, could they be retained by the wool for a sufficient length of time to permit the latter to pass through the machinery. Accordingly, numerous compositions are offered in the market as cheap substitutes for the more costly oil. As a rule, however, oil maintains its position in the estimation of the trade as the best and most economical lubricant, all circumstances being considered, though there are cases in which some of these compositions may be advantageously used.

A good quality of oil, very pure and free from acids, is the best, as it is retained the longest by the wool, and does no injury to the card clothing, nor to the colour of the material. The nature of the wool being worked will, to a certain extent, always influence the selection of the oil, but apart from this consideration, experience has shown that oleine is a cheap and very satisfactory lubricant. It is expressed from animal fats, and is specifically known as tallow-, lard-, and neat's-foot oils (see p. 1367). A recent writer on the subject advocates the oleine obtained as a bye product from the manufacture of stearine candles (see p. 585). But should the oil not be cleared from the sulphuric acid used in its preparation, the card clothing will be injured, the felting property of the yarn will be damaged, and the operatives who have to handle the wool will suffer in their hands and arms, the acid often destroying the finger-nails. Commercial oleine always contains less or more acid, the quantity varying from ½ per cent. upwards. Red oil is of a kindred nature to the above, and is usually similarly contaminated with mineral acid. A ready way of testing oils for mineral acids is to place a drop on blue litmus paper, which, if only a faint trace of acid be present, will turn red.

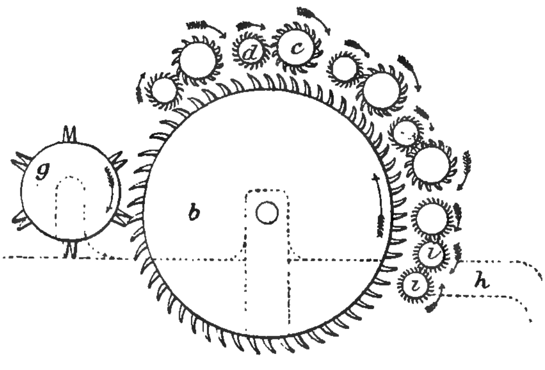
Of the compositions used, the following are regarded as good:—(1) Take of oleine 10 per cent., and boiling water 15 per cent., of the weight of the wool to be oiled; mix, and add a little sal ammoniac, sufficient to cause the oil and water to combine, after which it is ready for use. (2) Pour into a trough or tub 20 parts of oil, 10 parts liquid ammonia, and 5 parts water; mix with a wooden stick, inject steam, and allow the liquid to boil until the strong smell of the ammonia has evaporated; the mixture may then be applied in the ordinary manner. This latter is stated to be a useful and economical lubricant, giving uniform results, and neither injurious to the colour of the wool nor to the card clothing.

1449.



Lard and olive oil are, however, always the most reliable, and generally used when the best results are desired. The quantities greatly depend upon the state of the wool, but it will be found that 4–6 qt. per 100 lb. will ordinarily be sufficient. Where the blend, however, contains a proportion of mungo and cotton, this quantity will require to be exceeded.

1450.



The "fearnought," Fig. 1449, is the last machine employed in the opening process, and is used to perfect the work of the teazer in opening out the tufts or locks of wool, in order to facilitate the work of the carding-engine. It is composed of the framework *a*, containing the cylinder *b*, which is usually 45–50 in. diam., and makes 150–200 rev. a minute. Its surface, composed of wood, is covered with rows of iron teeth 1 in. long, and in shape like a dog's tooth, extending across the face, and set about 1 in. apart. The teeth of each row alternate with those of the preceding one. The small rollers, shown in detail and in section in Fig. 1450, *c*, are denominated workers, and generally revolve about 20 times a minute. The small rollers *d*, alternating with the workers, have a greater surface speed than those rollers, their function being to strip them. Both workers and strippers are clothed alike with one kind of teeth, set in a similar manner to those of the cylinder. The workers and strippers are carried upon bearers *e*, attached to the bend *f*, and a corresponding one on the opposite side. By means of the bearings *e*, the workers and strippers can be adjusted to each other and to the cylinder, according to requirement. The cylinder *g* is a fan, across the face of which are fixed bars of wood, each carrying two rows of straight iron teeth. At the back of the machine is the feed-apron or travelling lattice *h*, on which the wool is placed, and carried to the feed-rollers *i*. The direction of the arrows shows the course of revolution of the rollers. In operation, the rollers are all enclosed in a sheet-iron casing, which is continued underneath, and there perforated, to permit of the dust dropping out, whilst all fibre is retained. Its enclosure also enables the fan to develop and maintain a current of air.

The arrangement of the different rollers in this machine is on the same principle as prevails in all the carding processes, of which it may be called the first stage. The bottom feed-roller is set so that its teeth shall cut as it were into the circle formed by the extremity of the teeth of the cylinder to a depth of about $\frac{1}{8}$ in. The top feed-roller, whilst set back from the cylinder, must similarly work into the bottom one. The first stripper is set so as to clear the top feed-roller, which it does by its quicker revolution, and must be set to within $\frac{1}{8}$ in. or less of the face of the cylinder, so as in turn to be cleared by it. The workers must be set so as to dip their teeth about $\frac{1}{8}$–$\frac{1}{4}$ in. into those of the cylinder with which they must alternate; and each stripper must be set to take the wool from its respective worker, and, at the same time, return it to the cylinder. The course of revolution in each case is indicated by the arrows, and the particular effect is obtained in a great degree from the different surface velocities.

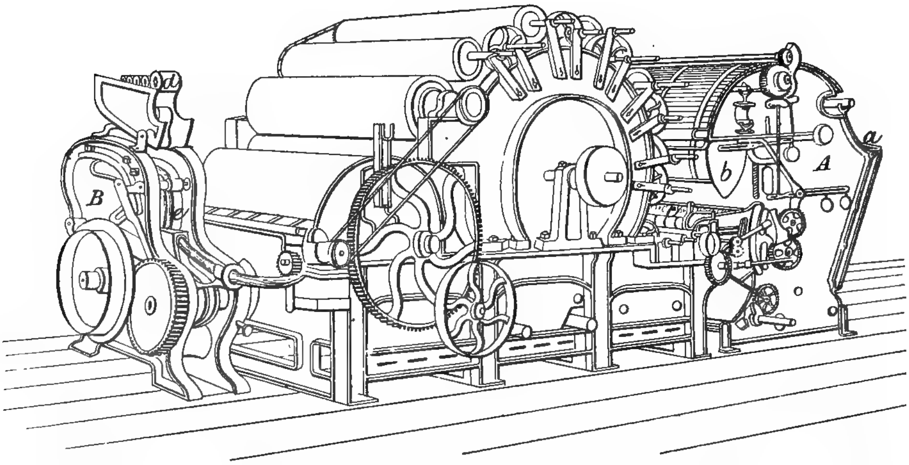
The operative takes the wool as received from the oiled blend, and feeds it by hand upon the travelling lattice, which carries it to the feed-rollers. Passing through these, it is seized and carried upwards by the teeth of the cylinder, some portion however being struck into the upper feed-roller. This is stripped by the first stripper working into that roller, and given over to the cylinder. The wool which the cylinder has already obtained is carried upward with great velocity, but is soon arrested by the first worker, which, though revolving in the same direction, does so at such a diminished rate of speed that it takes the wool from the cylinder into its own possession; but carrying it round, the worker is immediately relieved in turn by the stripper, which is revolving at a greater speed. The stripper instantly gives it back to the cylinder. The wool is again arrested by the next worker, when it follows the same course as in the last case. This is repeated until the series is gone through, when the wool will have been sufficiently opened to fit it for the carding-machine. From the last stripper, the cylinder carries it forward to the fan, which, revolving at a quicker rate than the cylinder, clears the wool therefrom, and throws it out at the front upon a sheet laid to receive it, and in which it is tied up and carried to the carding-room.

Scribbling, Carding, and Condensing.—These processes are simply stages of one and the same thing, namely carding. Up to this point, the operations have been designed to free the wool from dust, grease, burrs, &c., and to open the felted or matted portions. The machinery employed has been of a character appropriate for the work, the clothing of the various rollers, cylinders, &c., having been rough and strong. Scribbling and carding are intended to perfect this work, accomplishing by finer instruments that which the rough ones could not achieve. The entangled locks of wool are now separated fibre from fibre, the curls or undulations of the wool are straightened out to some extent, and the blend is more thoroughly intermixed than before, the whole being reduced to a perfectly homogeneous condition.

Carding machinery is usually arranged in "sets," one set being those machines which perfect the preparation of the wool for the spinning process. Usually in this country, or rather in the Yorkshire woollen districts, the set is composed of two machines, the scribbler and the carder with its condensor attachment. In some districts, of which New England (U.S.) may be cited as an instance, the set is composed of the scribbler, intermediate, and condensor. Where the best results are required it is necessary to use the three, or at least it may be regarded as advisable. There are many variations of form, and different systems of feeding these machines. It is not needful to describe these in detail; therefore a selection will be made of the most recently improved or perfected.

The English system of wool carding for the production of woollen yarn is perhaps as perfectly illustrated in the set of machines constructed by the firm of John Tatham and Co., of Rochdale, as by any now in the market. Good carding is to a great extent dependent upon regularity and evenness of feeding. This was previously and is now widely performed by manual labour, the process being to weigh a given quantity of wool, and spread it equably by hand over a measured space of the feed-lattice. A good result is thus entirely dependent upon the conscientious performance of duty and the skill of the labourer: qualities that are not always to be had. The difficulty of securing them has led, as in many previous instances, to the invention of an automatic method of weighing and feeding the scribbler-card. This is of American origin, and is named the Bramwell automatic feed. By this invention, results are achieved surpassing in quality the best efforts by hand. The machine forms an attachment to the carding-engine, and is shown at A on the right of Fig. 1451. The wool is fed promiscuously at the back, a large supply being placed in the feed-box or receptacle *a*, which has a grating at the bottom, to permit dust or similar refuse to pass through. At the rear of this box, is an elevator, a toothed apron, the teeth of which are of peculiar construction. These teeth take hold of and carry the material upwards, until it arrives in contact with an oscillating comb, which has a long slow sweep in front of the apron. The function of this comb is to take off the surplus wool from the apron, leaving only an evenly-distributed layer amongst the teeth of the latter. On the descending side of the apron, it is brought into contact with a short stripping-apron, the action of which is much quicker. This is produced with flexible strips of leather, which sweep off the wool from the teeth, and convey it in connection with a hollow or concave shell into a weighing-scale *b*. This scale is composed of two parts, kept together by weights, the whole being suspended on steel knife-edges, and balanced with movable weights, which can be fixed to weigh any desired weight. When the scale has received its proper amount, it liberates a small trigger, which causes a projection to come into contact with the teeth of a revolving disc, connected with an automatic clutch that disengages the driving-belt actuating the toothed apron, and stops the further delivery of material to the scale, which now remains at rest. When the proper moment arrives, the parts of the scale separate, and deposit the wool on the feed-lattice *c* in a loose open condition, well suited for the cards. The scale then closes, and is carried back for more wool, the toothed apron recommencing its revolution, and the process going on as before. In the meantime, the lattice which has received the wool has moved on, and has brought up a clear space on which to receive the next discharge.

1451.

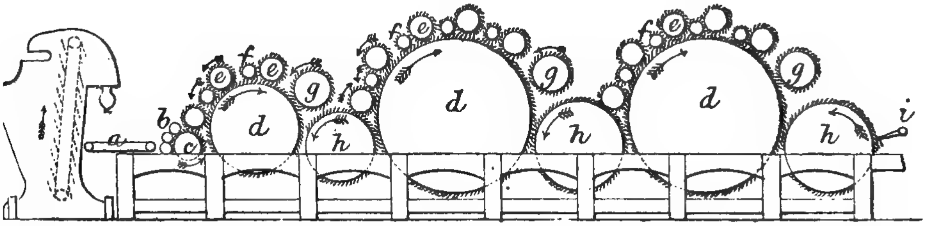


This attachment to the card has met with great favour in America, and has latterly been received with approbation in this country, numerous manufacturers of eminence having adopted it. It takes no more room than the ordinary lattice-table, is complete, perfectly automatic, and requires but little power to drive it. Besides delivering the wool with great regularity, it mixes and opens it, thereby improving its condition for the card. It takes out a considerable portion of the foreign matters the wool may contain, rendering the carding much easier, and preserving the cards. An increased production of 20–30 per cent. is obtained, whilst considerable economy is effected in the matter of wages, one man being able to superintend three sets of three cards to a set. It is so constructed as to seldom get out of repair. The qualities it possesses in combination are that it delivers a uniform quantity over a given space at uniform intervals of time. All these factors can be varied separately or together, so as to produce any modification of the result that may be desired.

The card may be of various widths, and single or double; that is having one or more cylinders. Fig. 1451 shows a single card with the Bramwell feed attachment A on the right, and Tatham's patent balling-machine B on the left. This is another ingenious and comparatively recent invention, the function of which is to take charge of the carded material, and make it ready for the next machine. The wool is coiled or wound upon small wooden bowls or bobbins. The machine has a supply of these bowls *d* placed upon its top, whilst another is held between two discs *e*, shown between the sides of the machine. The wool comes from the doffer of the card in the form of a sliver: a soft untwisted rope, which is then carried through a revolving tube, the action of which imparts more cohesive power to the loose fibres, to enable the sliver to be drawn from the bowl in the next process. When the bowl between the discs is filled, the latter separate and allow it to drop out into a box, and immediately thereafter an empty bowl from those on the top is brought down and placed between the discs, which now close and hold it as before. After the discs have made a few revolutions, in order to attach the sliver to the empty bowl, the sliver hitherto unbroken from the full bowl is automatically severed, and the bowl may then, at the convenience of the attendant, be carried away. This system is highly recommended where the plan of feeding the intermediate card with sliver is in use.

Having described these attachments, the card itself demands notice. As before stated, the cards may have one or more cylinders, or "swifts," as they are usually termed. When two cylinders are used, there are no important differences in the mechanism, the only alteration necessary being that the clothing of the rollers and swift shall be finer in the second than the first. Fig. 1452 illustrates a section of a double wool-carding engine, and its introduction will serve to show the manner of connection between the two parts, and the ordinary method of feeding the machine. They often also comprise a "breast," or a smaller cylinder which is also shown. In the ordinary feed, the wool is placed upon the travelling lattice *a*, and a given weight is as evenly as possible spread upon regular, marked spaces. In this case, the automatic feed attachment is shown also. This lattice carries the wool to the three small feed-rollers *b*, which deliver it to the "licker-in" *c*, which in turn yields it to the rapidly-revolving swift *d*. The series of rollers shown on the periphery of the breast and the large cylinder are termed "workers" *e* and "strippers" *f*. Each worker has its connected stripper. The large rollers *g* are called "fancy rollers," and the larger ones *h* "doffers." The second part is a duplication of the first, possessing in addition merely a doffer comb *i*, which by its rapid oscillation strips the doffer, and delivers the material in the form of sliver to the pressure-rollers, whence it is conveyed by one of several different methods in vogue to the condensor, when no intermediate is in use.

1452.



All these rollers are clothed with appropriate card-clothing, composed of wire teeth bent at given angles, and set in sheets of leather, or of a compound of cotton and indiarubber; these sheets form what is called the card "foundation." Card-clothing is made in the form of sheets, 4–6 in. wide, and of length sufficient to extend across the breadth of the machine. The number and fineness of the staples or teeth vary according to requirement and the position they have to occupy in the machine. These sheets are nailed across the face of the cylinder with great care, so as to present a perfectly even surface, curving only to the periphery of the cylinder, doffers, workers, and fancy, for which they are generally used. "Filleting" is composed of long narrow strips usually ½–2½ in. wide, and long enough to cover the roller in one piece. The smaller rollers, on which the clothing does not last so long as on the large ones, are generally clothed with filleting; these are the strippers and angle-strippers. One end of the fillet, being made fast to the roller, is then wound helically over its surface, and secured at the other side.

The arrangement of the teeth of the clothing is of importance, in order to secure satisfactory results. In fact, without a proper position and accurate setting, regard being had to the relation of speed each bears to the other, and to the direction of revolution, such a result cannot be had. The old-fashioned way of adjusting the rollers was by sight, but this was seldom satisfactory. A gauge has of late years been introduced, and has come generally into use. By its means, accuracy is obtained and much time is saved.

A brief explanation of the action of the cards may here be given. The "licker-in" takes the wool from the feed-rollers, the card-teeth operating as hooks. As the periphery passes round to the cylinder, the teeth are then in the act of ascending (the bend being thus in the opposite direction), and presenting facilities for being stripped of the wool they have acquired. Here the cylinder, revolving 80–100 times, equal to a surface velocity of 1000–1200 ft. a minute, and its teeth bent upwards, takes the wool from the licker-in, and rapidly carries it forward to the first worker *e*.

The teeth of the worker are bent in the opposite way to those of the cylinder; and though its revolution is in the same direction, its surface velocity is so much less that it takes the wool from the cylinder, a sharp carding or combing of the fibres taking place. As the worker carries the wool slowly round, it is relieved of its burden by the more swiftly revolving stripper *f*, whose teeth are bent upwards, and work against the back or smooth side of those of the worker, at the point of contact of their peripheries. The stripper as it carries the wool round presents the smooth side of its cards in turn to those of the cylinders, whose speed again enables it to take possession of the wool, which it then carries forward to the second worker, to which it again yields possession, and the operation just described is again gone through; this is repeated at each succeeding stripper and worker, until all have been passed. The next roller to which the cylinder carries the wool is the "fancy," whose function is quite different from that of the workers or strippers. This revolves at a high velocity in the same direction as the cylinder, yet though their teeth are set opposite to each other, its action is not to strip the cylinder—the actual passage of the teeth being back to back—but to raise the wool to the surface of the cylinder teeth, so that it is easily taken possession of by, or rather is thrown upon the teeth of, the slow-moving doffer, which are arranged with the bend upwards, in order to receive and retain it, until stripped by the first roller of another cylinder's set (as shown in Fig. 1452) or cleared by the doffer-comb at the end of the cylinder's work. The work of the scribbler is now concluded, and, if well performed, the basis of a good yarn is laid.

Usually a set of cards is linked together in working, the product of the scribbler being automatically carried to the "intermediate," and that of the latter to the condensor card. This is done to obviate certain defects of the scribbler, which has a tendency to deliver the wool in an uneven sheet from the last doffer. The purpose of the intermediate feed is to so present the wool to the next machine that their irregularity shall not lead to defective results. There are a considerable number of these "feeds," but the most characteristic are those known as the "Scotch feed," "Marsden and Blamire's feed," and the "ball feed."

In the Scotch feed the wool is doffed from the scribbler doffer by the comb, and delivered upon a narrow travelling apron in the form of a sliver 3–6 in. broad, which passes through a series of rollers, whose object is to compress it and secure its adhesion whilst in transit to the next machine. From these rollers, it ascends to a travelling apron or belt arranged overhead, upon which it is carried to a point over the lattice-feed of the next machine. Descending here, it is given to a travelling carriage, passing between two rollers as it is carried from side to side of the lattice-feed. The carriage lays the sliver obliquely across the feed, the edge of one layer overlapping that of the preceding to nearly half its width, by which means a uniform layer or sheet of material is formed for delivery to the card. This, entering the feed-rollers obliquely as deposited, has its inequalities to a great extent obliterated.

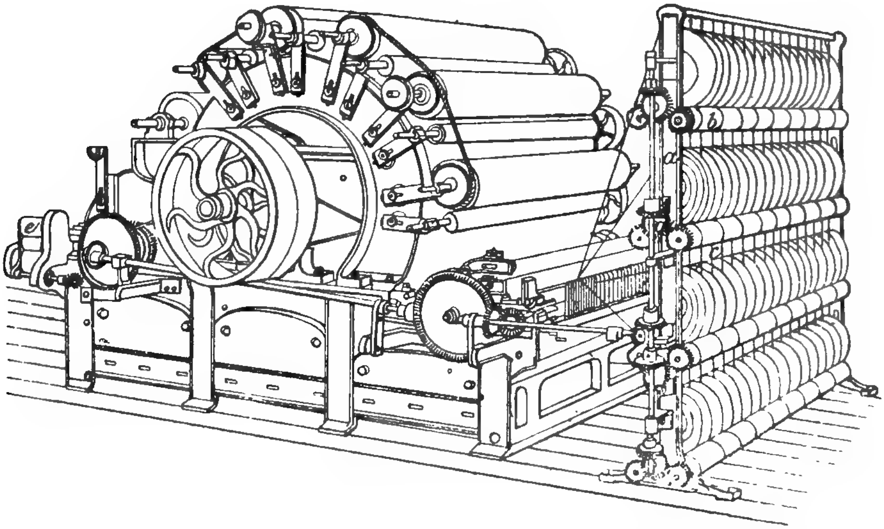
The arrangement known as Marsden and Blamire's feed, though not very different in principle, diverges considerably in its details. As the film of wool is doffed, it is laid upon a travelling lattice, which moves away from the doffer, and delivers the material through several guide-rollers to another lattice, mounted on a carriage underneath the top lattice, and which moves inwards and outwards, that is towards and from the doffer, thus causing the scribbled material to be deposited in layers until a sufficient thickness has been formed. The carriage lattice upon which the wool is thus laid, however, moves in a direction transverse to the upper one and to the direction in which the wool is delivered from the machine. In this manner, the scribbled material is delivered sideways to that in which it has been carded, as in the preceding feed, and passing between a pair of rollers, is received by another, and wound into a lap. When fully formed, this can be removed without stopping the machine.

This feed is very suitable for a low description of work, as it obviates the breakages of sliver that are apt to occur when the preceding form is used. It will be obvious that the fibres of wool in passing through the scribbler have been laid approximately parallel, and are doffed in that condition. The transverse delivery of the lap to the next machine causes the fibres to enter sideways, by which the inequalities of the lap are eliminated. This has also the effect of destroying the parallel arrangement of the fibres, crossing them in different directions, and so aiding in the production of a crossed fibre condensor thread, the best arrangement of the material in a thread for cloth which has to be shrunk or milled in the finishing process; it also assists materially in the production of a full nap upon the fabric, the end of every fibre lying on the surface of the threads. This system of feeding is in most general use where the "set" consists only of the scribbler and condensor.

One or other of the three systems of connecting or feeding the succeeding machines from the scribbler, or modifications of them, will be found everywhere in use. Special circumstances will always decide the adoption of the most suitable.

The cheese-shaped balls of wool from the scribbler, Fig. 1451, are taken to the "intermediate," and to a greater or less number as required are placed in a creel or bank *a* shown in Fig. 1453, an illustration of the intermediate carding-engine. As given, it represents a machine 60 in. wide, with one cylinder, six workers, six strippers, "fancy," and doffer. In the creels, the balls rest on their edges upon two rows of rollers *b*, and are maintained in the vertical position by slight bars *c*. The rollers are made to revolve and unwind the sliver from the balls by means of the bevelled gearing at one end of the creel, as shown in the figure, thus delivering the sliver without strain, which, if permitted to occur in a slight degree, would attenuate it, and thus render the product irregular. The slivers are conducted between a series of vertical pins, to prevent any overriding and uneven distribution as they pass through the feed-rollers, and thence through the series as named above. These, being precisely similar in their functions and details, except in the matter of clothing, which is finer, need not further be noted.

1453.

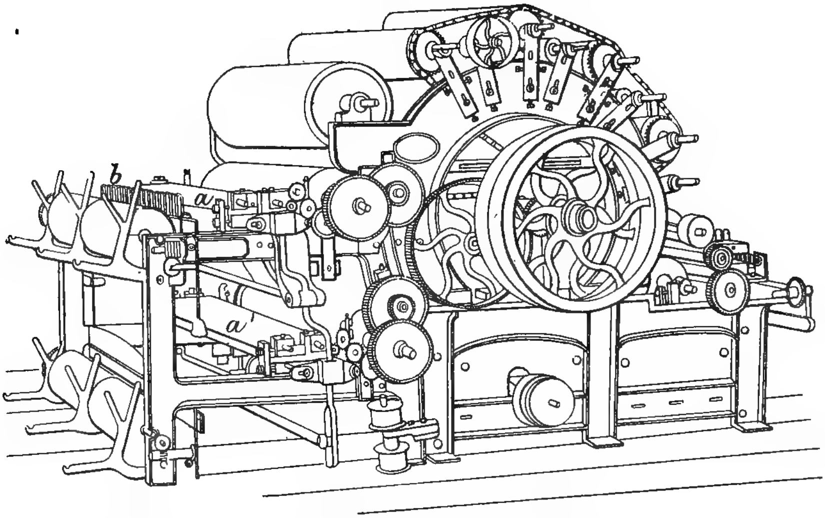


Emerging from the intermediate card, the wool is doffed in the form of a flat sliver, which, by an apparatus, is concentrated or condensed from the width of the machine (in this instance 60 in.) to about 4 in. wide, and which, in its passage from this machine, is compressed between the small rollers *e* seen on the left of Fig. 1453. It is then conveyed by one or other of the feeds, or modifications thereof, to the finisher-card, Fig. 1454, which is similar to the preceding, excepting in the feeding apparatus being different, and more like the Scotch feed previously described. Here the carding is completed. Attached to, and working in combination with it, is the condensing-machine, by which the carded wool is delivered in narrow ribbons from the doffers—one or two, as it may be single or double—and which, passing between the rubbers, are, by a rapid transverse movement of the leathers, rolled or condensed into a coarse round thread. The doffer-cylinder of the condensor-card is modified, by the clothing being divided, so as to form rings separated from each other by given spaces. The effect of this is that the film of wool is doffed by the comb in narrow ribbons or strips, instead of, as in the preceding cases, in one sheet. The machine shown in Fig. 1454 represents the latest make of the double rubber-condensor. After the sliver strips or ribbons leave the doffer, they are conducted between the pairs of leather aprons *a a'*, each pair forming a "rubber." These aprons are stretched each between two rollers, and neatly sewn together, so as to form a travelling apron when the rollers are made to revolve. One of each pair is placed above the other, near to but not quite in contact. Appropriate gearing at the side causes them to revolve, by means of which, the ribbons of wool would be carried forward in that form, did not another movement intervene to prevent it. This is a lateral movement of the leathers in a direction transverse to that of their revolution, each leather moving in this manner in the opposite way to its associate. The effect is to rub the sliver strips into a round thread, as stated, in the same manner as if they had been rubbed between the palms of the hands. The strips of sliver are thus both carried along and rolled as they come from the doffer, this being done without their suffering attenuation. These aprons extend across the machine, and vary in width from 12 to 20 in., according to the work they have to perform. The condensed threads, after they leave the rubber, are conducted through a guide-comb *b* and upon condensor-bobbins placed in the standards to receive them. These when full are removed and are ready for the creel of the mule.

This form of condensor is in general use all over Europe, and, in the opinion of the best practical judges, is the most useful and perfect condensor in existence for all round work. In the American woollen trade, another kind is in use, called the roll-rub condensor; but, as practical writers in the United States admit the superiority of the foregoing, it is not necessary to describe it.

Carding is probably the most important of all the processes of woollen manufacture. Nothing tends so much to success as its proper performance, and nothing so much militates against that

1454.

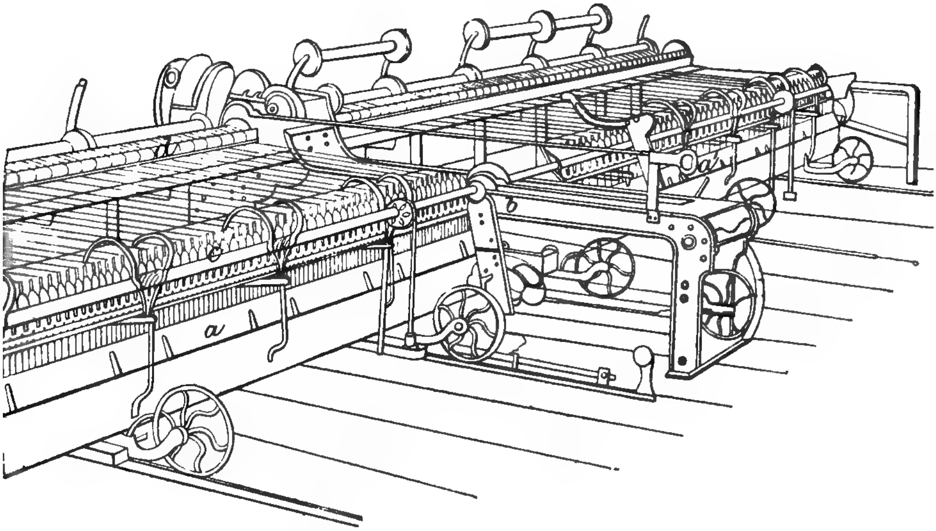


result as when it is badly done. The essentials of good carding are numerous, and include a proper arrangement of the machinery; nice adjustment of the parts, especially the rollers; careful clothing; good grinding; flocking; and correct relationships to each other of the speed of the cylinder, workers, strippers, fancy, and doffer. These are matters that call for attention before the commencement of work. During working, there are equally numerous conditions that require examination. Care should be taken not to overload the machinery with wool, which would result in defective work, as the cards would pass it on without sufficient treatment. The cards should never be permitted to fill up either with dirt or wool, as the material in process is thereby apt to be rolled. The technicalities of the treatment of wool and the management of the machinery are so numerous that to enter into detail upon them would extend this article to the compass of a volume.

Spinning.—Woollen yarn is usually spun upon the mule; there are several continuous spinning machines, but though invention has been directed for a long time to the construction of a good continuous spinning-frame, no such machine has yet achieved a commercial success. The mule, as is well known, is an adaptation from the cotton trade, like the carding engine and many other machines in the various sections of the wool manufacture.

The woollen mule (Fig. 1455) is much simpler and has far fewer spindles than the cotton-spinning mule. In general appearance it is much like the other, and consists of two carriages *a a'* mounted on wheels with the headstock *b* placed between them in the middle. Each carriage is fitted with a number of spindles *c*, usually 500-600. The frame consists of the roller-beam and creel carried upon the usual standards. The difference in the nature of the fibre of wool from that of cotton precludes the use of drawing-rollers, as in cotton-spinning. The woollen mule is therefore only furnished with one row of fluted rollers, provided with a corresponding row of top rollers *d*. The condensor-bobbins being supplied to the frame, the threads are drawn off, passed between the rollers, and attached to the spindles. The mule is then ready for commencing work. Simultaneously the spindles begin to slowly revolve, the carriage to draw out from the roller-beam, and the rollers to deliver the condensor-threads. When the carriage has traversed about half its journey outward, the rollers cease to deliver the material. The carriage proceeds on its course, and the spindles continue revolving, by which means the condensor-threads delivered from the rollers are gradually attenuated, until, by the time the carriage has reached the extremity of its traverse, this is completed. The thread, however, as yet is only soft and loose, and must be rendered comparatively firm and strong. In order to accomplish this, the revolution of the spindles is greatly accelerated, and the thread rapidly twisted. This twisting takes up the length of the extended thread, in order to allow for which the carriage is made to move in a few inches as the twisting proceeds. When this is completed, the spindles are automatically arrested, and for two or three turns have their movement reversed to form the "backing-off process," as the unwinding of the several turns of yarn upon the spindle-tops is called. This being performed, and the slack simultaneously taken up by the "fallers," the carriage proceeds inwards, winding the threads upon the cops until the spun portion is all thus disposed of. The process then recommences, and is repeated in all its details, recurring until the set task is accomplished. When the spindles are filled, they are "doffed," that is, cleared, and a new set is begun.

1455.



The yarns thus spun may be either for warp or weft. The former constitutes the longitudinal threads of a woven fabric, and is usually well twisted; the latter forms the transverse or cross threads, and generally contains rather less twine than that intended for warp.

Manufacturing.—The processes up to this point form the first half of those comprised in the term woollen manufacturing, and are termed woollen spinning. The second half, or manufacturing, will require comparatively brief treatment.

The woollen thread as it comes from the mule will be natural, grey, black, or any other colour, according to the component parts of the blend from which it has been spun. When dyed in the loose fibre, wool is termed "wool-dyed"; when in the state of yarn, "yarn-dyed"; and when in the woven fabric, "piece-dyed."

Twisting or Twining.—Woollen yarns are generally used in a twofold form: that is, two threads are twisted together to obtain strength, bulk, and variety of pattern. This twisting process is done upon the mule, which is generally adapted for both spinning and twisting. In combining two threads, care must be taken to twist them in a direction opposite to that in which the individual threads were spun. This is in order to prevent it afterwards running into kinks. The twisting is performed by placing the threads in the creel, bringing them under the rollers, and attaching two threads to each spindle, when the twisting is performed as in the spinning process. To make self-coloured twist only needs the combination of two threads which are alike. To produce fancy yarns, it is necessary to combine different, which may be harmonious or contrasting shades or colours of yarns, and which may also be of different materials: wool, silk, cotton, flax, China-grass, or other fibrous materials. Although twisting is ordinarily performed upon the mule yet it is in process of being superseded. Messrs. Sykes of Huddersfield have introduced into the market a twisting-frame which has been extensively adopted, and is found to give very satisfactory results. In preceding articles (see Rope, pp. 1699–1701; Silk Manufactures, pp. 1751–3) a more recent invention, a doubling-winding, and a twisting-frame, made by Thomas Unsworth of Manchester, has been referred to and illustrated. The employment of these two machines for twisting purposes effects a very large economy when compared with the ordinary method, as is demonstrated by the following figures. At an important manufacturing establishment at Tourcoing in N. France, where these machines have been introduced, a comparison has been instituted, and the following results arrived at:—A 200-spindle machine making on the top or delivery spindle 4500 rev., and front spindle 4500 = 9000 rev. per minute, working 3-fold 42's worsted, produces in a week of 81 hours, 420 *kilo.* of twisted yarn of a very high quality. This is done at a cost in wages of, for winding, 75 *fr.* 60 *c.*; for twisting, 20 *fr.*, total 95 *fr.* 60 *c.* = 22 *c.* per *kilo.*, as against a production in the same mill on a good ordinary system, and a machine containing the same number of spindles, running the same hours and working the same yarns, of 250 *kilo.*, at a cost for winding of 45 *fr.*, for twisting, 40 *fr.*, total 85 *fr.* = 34 *c.* per *kilo.* In the latter system, two girls are required at the twisting-frame, whilst in the former, only one is needed. It is obvious that a regard for economy will compel the adoption of the improved methods now being introduced to the notice of manufacturers.

Designing.—At this stage, the services of the designer are called into requisition. Designing patterns for fancy woollen cloths implies the classing or arranging of the contrasting and harmonizing shades or colours, both of the warp and weft, by the combination of which in a fabric chaste and saleable patterns are produced in the cloths. Many colours may be employed in the warp, which, if crossed by a plain weft, would produce stripes; or an equal, greater, or less number of colours may be used for the weft, when a checked effect would result. By the transposition of these coloured threads in the warping and weaving, an endless variety of plaids and stripes of various dimensions can be produced. Combinations of patterns may also be obtained in great number from the use of two or three colours of warp and weft. As each lot of yarn is twisted according to instructions, a ticket is generally attached, expressing the lot and numbers, the length, and the breadth. The length is stated in "strings" of 10 ft. or 120 in., and the breadth in "porties" of 40 threads each. When the warp is to have stripes in it, one set or complete pattern is usually drawn on the ticket as a guide to the warper and weaver.

Warping.—The warping mill, in which the yarn is combined into a warp, is a large vertical reel of about 20 ft. in circumference, or two standard "strings." The hand warping-mill is only half the size of the preceding, and in small manufactories is yet in use. The length of the warp is varied according to requirement. The best way of warping is to arrange the threads in even numbers, say 40, 44, 48, 52, 56, or 60 threads in a "bunch" or "gang," and to divide them into four equal parts, that is 10, 11, 12, 13, 14, 15, on the under leash-pins. The number of bobbins or cops required should be set in the creel, and the threads be conducted through the eyelets of the guide-pins, one half above the other, each thread thus being alternated, which will leave a space between them. The warper then collects and ties the whole bunch of threads together, inserts his thumb into the open space, and crosses every thread upon the top pins, so as to form the leash. The reel is next set in motion, which is continued until the length of the warp has been reeled, when the leash is again taken on the pins, and this process is repeated a sufficient number of times until the proper quantity of threads is obtained to form the width of the warp or chain. When this is completed, the end is securely tied to prevent entanglement, the leashes are secured with bands of yarn, and the warp is well marked at each "string" for the guidance of the weavers. To each warp is also supplied a number of "listing" threads, of stronger yarn than that forming the bulk, from which the lists or selvedges of the cloth are woven. About 100–120 of these threads are required to form the two selvedges of a broad cloth, and about half that quantity for a narrow width fabric. The warp is usually made in the form of a chain in the woollen trade. This is simply a peculiar arrangement of the warp.

Sizing.—The nature of the raw material, and the method of manufacture of the woollen thread in which the fibres are crossed in various directions, render the process of sizing a necessity. The purpose of sizing is to lay smoothly in a parallel direction all the protruding fibres on the surface of the yarn, so as to diminish the friction; and to solidify the threads and increase the strength, to fit the warp for the reception of the weft, and to enable it to withstand the strain occurring when the latter is driven home by the "slay" or batten. The process is of considerable importance, as the production of good cloth requires that it shall be well and evenly performed. It is also highly necessary to the weaver, as when properly executed, her labour is much less; and, weaving being usually piece-work, the production is greater, and her earnings larger. The chain or warp is generally immersed in a vessel containing the sizing preparation, and when thoroughly saturated it is squeezed out, either by hand or by a wringing-machine constructed for the purpose. The "size" is usually some strong glutinous matter, sufficiently firm to lay down the somewhat refractory fibres of the wool. A good size is composed of prepared rabbit skins dissolved by boiling in water for about three hours. After the warp has been properly sized, it should be thoroughly dried, which is accomplished either by laying it at length, or winding it on a drying-machine to prevent injurious consequences.

Beaming.—Beaming is the winding of the warp upon the loom-beam. It is accomplished by the aid of a simple machine called the "beaming-frame." The first care of the beamer is to lay or distribute the threads of the warp evenly in the ravel, a coarsely-set reed or frame, the upper part of which is removable, in order to permit of the warp threads being placed between the vertical pins or teeth, which having been done, the top or cap is secured. A rod, which fits into a slot or groove extending the length of the flanged beam, is next inserted into the end of the warp. The warp is then wound evenly and tightly upon the beam. Should the winding not be perfectly level, defects would be caused in the cloth, owing to the different tensions at which the warp threads would be woven, some being slack, and others tight, which would afterwards result in uneven milling, and other defects in the finishing processes. When the warp has all passed upon the beam, two rods are inserted in the leash formed by the top pins of the warping-frame, which, being tied together, secure the perfect alternation of the threads.

Drawing-in and Twisting.—The warp is now ready for attaching to the healds or harness. In the case of a new set of healds being required, the beam is suspended in a frame, or by means of strong cords, with the warp end falling a short distance down. The "healder" or "drawer-in" takes his seat in front of the healds, and a child assistant called a "reacher" sits at the back. The former opens the healds in succession, and puts through the eyelets a small hook constructed for the purpose, called a "heald-" or "reed-hook," into the eyelet of which the reacher inserts one or two threads, as the hook may be single or double, which are then drawn through to the front by the drawer-in. In this manner he proceeds until all the warp-threads are thus entered, and the drawing-in or healding is complete. Simultaneously with this operation the threads are also drawn into or through the reed by the drawer-in. One thread is drawn through the eyelet of each heald, and two through each space between the dents of the reed, when the design is to make a plain fabric; three, four, five, or six threads may be drawn through each reed space for various sorts of twills and fancy cloths. The warp is now ready for the loom, which introduces the last principal operation, subsequent ones being subsidiary to this, and variable according to the nature and purposes for which the fabric is intended.

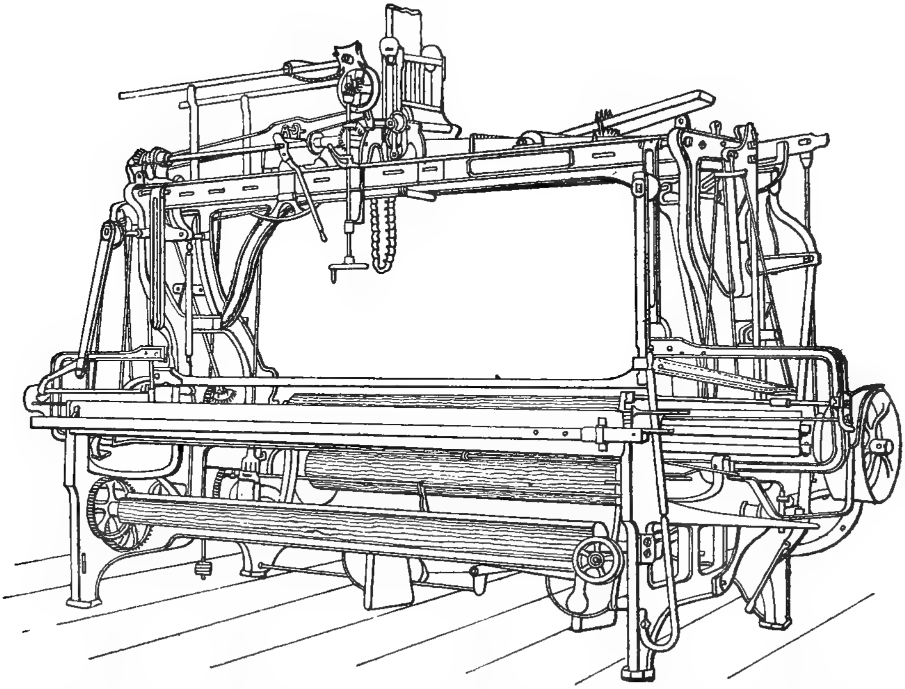
Weaving.—Weaving is a very ancient art, and in its origin consisted probably of simply interlacing reeds with each other in order to form mats on which the people of Eastern countries, with whom the art is supposed to have originated, might recline. These reed textures are made to this day in the countries referred to; and, amongst the Chinese, very largely, as may be inferred from mats being found amongst the articles of export to this country. From this simple process, the development of the art was extremely slow through thousands of years until the early part of the 18th century, when Kay, of Bury, in Lancashire, inaugurated the present grand epoch of mechanical invention by devising a plan whereby a weaver could throw the shuttle backward and forward across the loom by one hand, and which also enabled him alone to weave the broadest cloths; whereas, by the plan then in vogue, two weavers were required. Improvements followed each other in rapid succession, until by Dr. Cartwright's happy thought and mechanical skill, the automatic loom was designed and invented. This was about 1789, since which time the progress in developing and perfecting the loom has been simply wonderful, until now there seems little left to accomplish, unless it be to dispense with the presence of a superintendent altogether.

The capability of the loom as turned out of our first-class machine shops is something at which surprise may be justly expressed. It is questionable whether in the whole range of mechanism anything more wonderful can be found. Being supplied with warp and weft, properly adjusted, and connected with motive power, the loom with only small supervision will fabricate textures varying from the plainest calico to those of the most gorgeous beauty. The warp is opened, the shuttle with its cargo of filling is thrown between, leaving a trail of thread behind, which is driven home by the advancing lathe or slay, the latter immediately retiring to make way for the shuttle again, when the operation is repeated. This goes on not at a creeping pace, but with almost lightning rapidity, 200-400 transverse threads being put into the web per minute. At the same time, the cloth is being automatically taken up in front of the loom, and the warp delivered at the back with the most perfect regularity, ensuring thorough uniformity in the structure of the fabric. Plain fabrics, alike on both sides, twilled fabrics, plain on one side, or twilled on both, or patterned in various ways, can be produced with equal facility. Coming to more intricate textures, striped, chequered, and numerously variegated designs can be obtained as desired, by the aid of the many attachments invented for extending the capacity of the loom, either in plain, self-coloured, or variegated forms. With the Jacquard machine as an adjunct, the power of the loom in the variation of pattern becomes practically illimitable.

The Jacquard apparatus has been modified and adapted to many purposes. One of limited range, called the "Dobby," is used for the production of small patterns and of figured borders in cloths having a plain centre. Others are taken away from shedding purposes altogether, and adapted to work both rising and revolving systems of shuttle-boxes, by which means, from one to any number of picks can be obtained from one shuttle, and the whole number alternated according to desire.

These remarks will obviate the necessity of making detailed statements concerning the mechanism of intricate looms which the general reader would find it difficult to follow, and which to the expert are already well known. Fig. 1456 is a perspective view from the front of the well-known Dobcross woollen loom, so called from the town in which it is made. The firm from which this emanates, Hutchinson, Hollingworth, & Co., is of considerable repute in the woollen districts, and the loom represented is high in favour. A peculiarity is that the slay or lathe is suspended from the top of the loom, according to the old plan, but which, in some cases, it is deemed desirable to retain, even though regarded as antiquated. The Jacquard or Dobby with which it is mounted, is adapted to work from 3–34 shafts or heddle-leaves, and is on the double-lift principle: that is, its action is of the positive kind in both lifting and pulling downwards the heald-shafts in order to make a shed for the passage of the shuttle. In the single-lift, the arrangement is confined to lifting the healds, their depression or return being obtained by the action of spiral springs or weights underneath the loom. The unreliability of this plan is well known to practical men. Thus, when working, the healds are always being raised or depressed by positive means. This loom is constructed with three, four, or five boxes on the rising plan: that is, each box containing its shuttle is brought on a plane parallel with the shuttle-race, according to requirement, by being elevated or depressed to the position, according as it may have stood at the moment. Every change of position in the boxes requires the whole number to be moved up or down, as needed. In doing this, a great deal of inertia had repeatedly to be overcome in elevating the boxes, whilst their descent entailed a considerable shock, owing to the distance through which they had to fall, and the influence of gravitation. The former circumstance absorbed a great deal of motive power, whilst the latter entailed a heavy wear and tear. Both these defects have to a great extent been obviated by the introduction of a plan of balancing the boxes, by which they can be elevated or lowered with greatly increased facility, and which renders them much easier to control. A simple method of connecting the shuttle-box motion with that which controls the pattern motion, so as to ensure harmonious action, was for a long time a great desideratum. In patterned goods, it will be obvious that one thread less than the required number in the weft will cause a serious blemish in the cloth. This may easily occur through the breakage of the weft whilst the shuttle is crossing the shed; and when this happens at the moment when a change is about to take place, the loom may continue working, the automatic stopping motion failing to detect the lapse. In this case, it is compulsory to rely upon the carefulness of the attendant weaver, whose duty it is instantly to stop the loom, pull out the picks that have subsequently been put in, and reset the loom to commence correctly at the place where the defect occurred. To do this has not been an easy matter for the weaver, the box and the pattern motion having to be reversed, which, in the case of a cumbrous machine—as a large power-loom proves to be when it has to be operated by human power, and that generally a female—has often proved almost insuperable. In the best-arranged plan, much delay has

1456.



generally occurred, which in itself is an economic evil, greatly lessening the production. In the loom represented here, a plan is incorporated of controlling the picking motion and that for lifting and lowering the boxes, both of which are controlled by the pattern chain; so that whatever changes may be required to be made owing to broken threads, unweaving defective portions, or other causes, all the parts can be readjusted correctly with quickness and facility. In woollen yarn, there frequently occur variations in the thickness sufficiently great to cause serious defects in the cloth, in the event of the same number of threads being put into, say one inch of warp, when during the next inch a finer weft might happen to follow. This defect is obviated by the provision of an automatic regulation, by which the delivery of the warp is retarded or expedited according to the varying requirement of the yarn. Approximately even cloth thus results, which would not be the case were the delivery of warp constant and unvarying.

Such is the woollen loom as made at present. There are numerous other makers, whose machines are equally deserving attention with the one illustrated, and before deciding, an intending purchaser should carefully examine those in the market, and select the one that will best suit his requirements.

In weaving plain cloth, four leaves of healds are usually employed, though only two are necessary. These are arranged to work in pairs, as follows: 1–2, 3–4. The first two ascend and descend together, and similarly the second pair, each pair being linked in the treading-motion. If the threads of the warp passed in the same order through the healds, the consequence would be that the threads would be placed in pairs side by side in the fabric. But this is not the case: the threads being passed through the healds in the following order, 1–3, 2–4, the first two of these going together in the space formed by two dents of the reed, and the second pair in the next space. This order prevails across the width, until, at the sides, where more strength is required, the threads are doubled or run two together through one heald, and four in the reed space. Sometimes threads of other materials are used for this purpose. By this means, the weft thread is made to pass through the warp shed in such a manner that it shall be placed in an alternate manner under and over the threads of the warp. This constitutes a plain cloth.

The first departure or variation from the plain fabric is to the 3-leaved twill, in which every third thread of the warp is sunk in succession, the picks of weft passing *over* one and *under* two threads of the warp. This texture gives a diagonal pattern to the cloth on one side, the reverse being plain. In this case, the heald-leaves are actuated independently of each other, and not conjointly in pairs as above. This texture is termed the "prunel," or "blanket," and sometimes the "llama" twill. The 4-leaved twill sends the weft *under* three threads in succession and *over* the fourth, by which the latter is interwoven. The name of this is the "Cassimere" or "Kersey" twill. There are other variations of the 4-leaved twills, in one of which the weft passes under two and over two, making both sides alike, except that on the face or front the diagonal line, which forms the pattern, runs to the right, and that on the back or reverse to the left. Others are variations on this basis. The 5-leaved twill flushes four-fifths of the weft on the back, and four-fifths of the warp on the face. The number of leaves may be increased up to 16 or even more, but when they exceed 5, they are generally employed in woollen fabrics in conjunction with the jacquard attachment for the production of a variety of fancy patterns.

In the woollen manufacturing districts, weavers do not usually attend to more than one loom, as it is highly necessary for them to bestow upon their work the most careful attention, in order to prevent defects, the occurrence of which would damage the cloth in the estimation of the purchaser very considerably, and in some cases render it unmerchantable. These defects are technically called "broken picks," "doubles," "thick threads," "raws," "gerners," "flakes," "twists," and many others, which it is not necessary to stop to define. Warp threads occasionally break, and if the weaving is continued without these being repaired, a defect is caused. In piecing them, care must be taken to join them by means of a short length of thread, called a "thrum" or "beeting," of the same quality and colour as the broken one. These thrums are provided for the purpose.

To secure a full production and a proper quality of cloth, the overlooker, or "tuner," as he is called, should be careful to see that the parts of the loom are properly adjusted to each other, so that all will work together in harmony. Otherwise delays, fractures of yarn, and defects will be numerous, the quantity and quality of the production will suffer, and ultimately the reputation of the manufacturer will be injured.

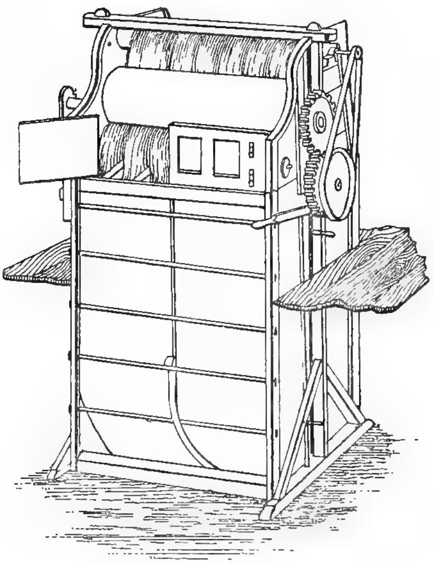
The actual production of cloth from a loom engaged in weaving woollen fabrics will be about 20 per cent. less than would be supposed from a calculation based on the assumption that the loom was continuously working during the hours allowed by law. The time thus lost is absorbed in changing shuttles: that is, supplying full for exhausted ones; piecing warp threads, and other necessary operations.

In weaving heavy close fabrics, it is best to saturate the weft yarns in soft water, and then place them in a hydro-extractor for a short time, so that the superfluous water may be taken out. This will greatly facilitate the weaving.

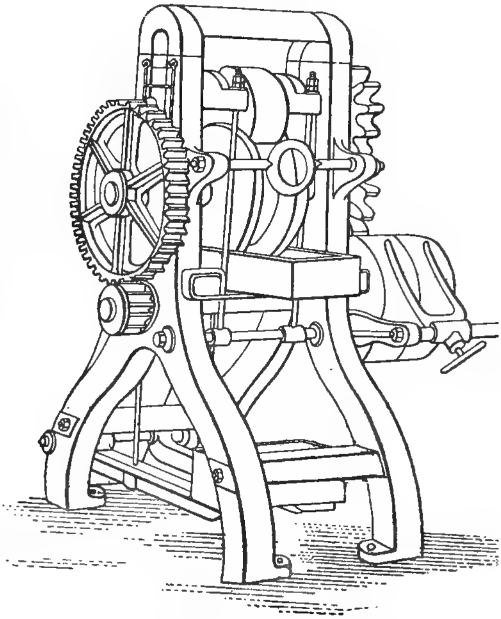
Knotting, Scouring, and Burling.—When the weaving is completed, the piece of cloth is taken out of the loom, and should, if it has been wet-woven, be well dried, properly lettered, and numbered, in order to preserve its identity through subsequent operations. Then it should be carefully examined, by being drawn slowly over a sloping board or table, in front of a northern light or aspect, and all knots and defects of weaving be removed or otherwise repaired.

The cloth should now be well scoured and washed, so as to cleanse it thoroughly from oil, "size," and other extraneous matter. A new washing-machine has recently been introduced, and is shown in Fig. 1457. The cloth is next to be thoroughly dried and slightly brushed, after which it ought to be again pulled over a sloping table, and have all the broken burrs, kemps or hairs, shives, motes, and other impurities removed. This process is called "burling." There are several plans of drying both yarns and cloth, of which the wringing-machine may be mentioned as applying to yarn, and the squeezing-machine (Fig. 1458), almost similar to the fulling-mill, for woven fabrics; but both these machines are objectionable, and have to a great extent been superseded by hydro-extractors, as shown in Fig. 357, p. 496.

1457.



1458.

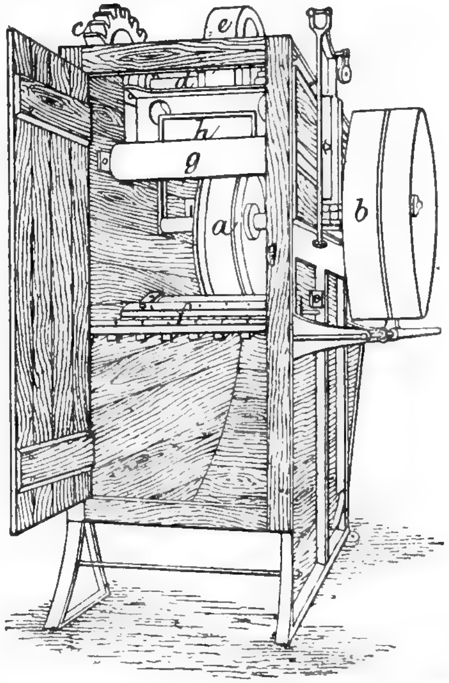


Milling or Fulling.—After leaving the burler, the cloth is ready for the fulling process. The first step is to sprinkle it with boiled or liquid soap, after which it is folded up by the lists or edges into a pile, and placed in the hollow receptacle of the fulling stocks. Here it is milled or hammered for two or three days, or until the fibres of wool become so interlinked in each other as to hide the warp and weft threads. During this process, the cloth is taken out of the mill five or six times, in order to have more liquid soap applied, so as to facilitate the milling process in every direction. This is the method of procedure when the ordinary fulling-stocks are used.

Of late years, however, an improvement has been introduced in the shape of the fulling-mill. This is to serve the same purpose, and is regarded as superior in many respects and for many purposes. Fig. 1459 is an illustration of this machine in its most improved form. The construction is quite simple, being composed of a shaft carrying a flanged roller *a* in the centre of its length, driving-pulleys *b* at one extremity, and gearing *c* at the other, from which a second shaft *d* placed over the first receives its motive power. This second shaft has also a roller *e*, which differs from the first in having no flanges, being arranged to work between those of the first-named. A slotted guide-board *f*, a carrier-roller *g*, and a contracting-tube *h* complete the mechanism, the whole, except the gearing and pulleys, being enclosed. The fulling-mill shown in Fig. 1459 differs from those commonly in use, in being larger in most of its details, having the rollers of greater diameter and the flanges deeper. The guide-board can be made with a slot or two more, and is also fitted with an improved stop motion, consisting of friction-plates that both start and stop the machine in less time than ordinary. The latter is of considerable importance, as, by its prompt action, damage to the fabrics in process of milling is often prevented when entanglement takes place.

The process of fulling with these mills is to soap the cloths as before, place the pieces in the mill, passing the ends through the grooves of the guide-board, over the carrier-roller, through the tube, and between the groove of the flanged roller, in which it is subjected to compression by the action of the top roller pressing upon it. This is continuously repeated until the cloth has been sufficiently shrunk or fulled, when it is replaced by another lot. Tested in work alongside the older form of the fulling mill, it has been found to do much more work, and of a better quality, the same cloth selling for fully 3*d*. a yd. more than when finished in the old machine.

1459.



Whichever instruments are used, the cloth should be milled according to the breadth required. Narrow cloths are milled down to 28 or 27 in. in width, whilst broad widths are reduced from 70 in. to below 60 in., varying anywhere down to 50 in. according to requirement. There are a large variety of fancy woollens that are only subjected to comparatively little milling, or about 10 hours, one-fifth or one-sixth part of this time being occupied in examination of and soaping the cloth. That constitutes "half-milling." Single-milled cloth requires subjecting to the treatment for 12–20 hours; double-milled, 24–40 hours; and treble-milled, 48–60 hours; all inclusive of the time required for examination and further supplies of the milling liquid or soap.

Finishing Processes.—Woollen cloths as they come from the loom are far from being a merchantable article in the ordinary acceptation of the term. The processes to go through before the soft, lustrous, and beautiful finish of the fabrics with which we are familiar is obtained are numerous and almost as important as those that have been already described. They consist of the following: fulling; tentering; 1st raising; 1st cropping or cutting; 2nd raising; 2nd cutting; pressing; steam boiling, &c.; 3rd raising; 3rd cutting; burling and fine drawing; brushing and steaming; 2nd pressing; steaming.

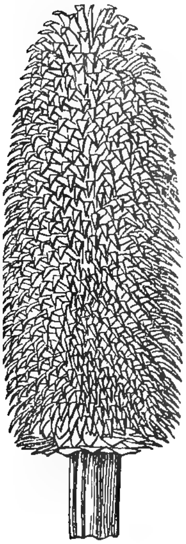
At this point, it will be well to summarize the requisites of a good cloth, or rather the conditions necessary to produce one. First, good sorting of the wool, which gives an even thread and prevents waste; thorough cleansing, essential to the production of good colours, and satisfactory working in every stage. After this, the wool should be well dyed, teazed, scribbled, carded, and slubbed, and carefully spun and woven. The preparatory processes before milling should be properly gone through, the milling well executed, and the fabrics afterwards thoroughly washed in order to remove all traces of grease, oil, or soap that may remain. The details of all these processes require attending to carefully and conscientiously. Any negligence is sure to result in blemishes, and these cannot be eliminated or rendered permanently invisible in the after stages. It takes much more trouble and labour to hide a defect than to keep it out.

After milling and scouring or washing, the cloth should be "cuttled," or folded up closely and laid on the shed floor for a few days. This improves the condition. When it has to remain in the "balk" state, or have its progress arrested some time at this stage, it should be straightened on the tenter-frame and dried, but care must be exercised in seeing that it is not overstretched, either in width or length.

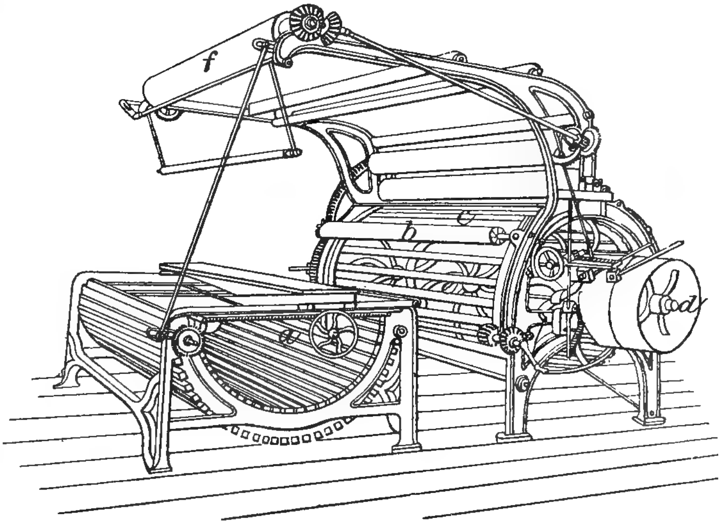
First raising of the nap.—Woollen fabrics rarely show the interlacing of the threads so visible in most other textures. These are effectually hidden by milling in the first instance, and subsequently by the raising of the nap. "Raising" is an interesting process, and consists of scratching up the surface fibres of the wool upon the face or front of the cloth. Formerly it was done by hand, the fabric being thrown over a frame, in the front of which stood the workman with his hand teazle-frame, with which he scratched the surface whilst a companion on the opposite side raised that portion. This process was a very laborious one, and has to a great extent been superseded by the introduction of the "raising-gig."

The teazle, Fig. 1460, is the ripe burr or head of a thistle-like plant called *Dipsacus fullorum*, which is cultivated in several parts of this country (Wiltshire, Essex, Yorkshire), and in many parts of France. Those of Yorkshire are most highly esteemed, and command the highest price. As will be seen from the illustration, the head is cone-shaped and formed of or covered by a great number of hooked points, all curved in one direction downward. These hooks are strong but pliable, slightly elastic, and very smooth, rendering the heads highly suitable for employment in this process. The teazles are cut from the plant with a stem 2–3 in. long, and inserted in an oblong frame called the teazle-rod, with the hooks pointing towards the base, and two teazles in height. When hand-raising is the system employed, these frames are small, such as can be easily wielded by hand, and are furnished with a handle. For the "raising-gig," Fig. 1461, as the teazling machine is called, the frame is about 4 in. in width, and of a length to extend across the gig-cylinder.

1460.

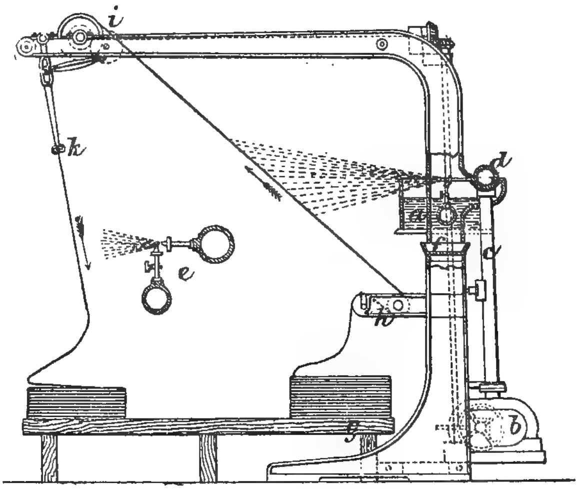


1461.



After the cloth has been evenly stretched and dried in the tentering-frame, it should be thoroughly wetted on the face or front side with soft clear water, and then folded and left to lie in that state for a day or two. This damping is now performed very efficiently by mechanical means. Fig. 1462 represents a "dewing-machine" used for this purpose, which is of recent introduction. It is constructed to take the ordinary width of a raw or unmilled cloth, but can be made wider or narrower to suit special purposes. It is an ingenious invention, as the following brief description will show. A cistern *a* containing water is arranged in the middle of its height, and extends across the breadth of the machine. Through the length of this trough, and immersed in the water, is laid a pipe, into which a number of nozzles are vertically inserted, these being supplied with taps to close them when required. Behind the machine, a patent blower or fan *b* is arranged with a wind-pipe, up which the blast is conveyed to a second horizontal pipe *d*, that, like the former, is supplied with nozzles, but in this case they are inserted so as to project in a lateral

1462.



direction to the tip of the water nozzles. The arrangement is clearly shown in the enlarged view of these parts given at *e*. At *f* is a trough in which the waste water is received.

In working, the piece of cloth to be dewed is placed on the platform at *g*; the end is passed over the first and under the second of the pair of rollers shown at *h*. It then ascends in an inclined direction to the head of the machine at *i*, receiving the spray in its passage. The operation of the fan sends a strong blast from the air-nozzle across the top of the water-nozzle, which causes a vacuum therein, leading the water to ascend to the top, when it is blown away in fine spray against the surface of the cloth as it travels upwards to the head, and, descending therefrom between the rollers *k*, is plated by their oscillatory action upon the opposite end of the platform from which it started. By means of this machine, 15–20 ends of cloth can be damped per hour. A damper enables it to be set to throw any quantity of water from ½–6 lb. upon each piece or end.

After the cloth has been properly conditioned by the ordinary damping or dewing process, it is conveyed to the raising-gig, Fig. 1461. This machine is usually constructed about 65 in. in width on the teazle, but can be made much wider if required. It is shown in the illustration with recent improvements, such as the revolving turntable scray *a*, and expanding breast-roller *b*. The chief part of it is the teazle-cylinder *c*, mounted upon the shaft *d*, which is furnished with driving-pulleys. The cylinder is constructed with 16 oblong spaces *e* around its periphery, for the reception of the oblong frames called "rods," into which the teazles are inserted, fixed by means of their stems; one side of the rod is composed of two parallel bars, having a small space between them for the admission of the stems. The rods are also strengthened by cross-pieces, so that, when inserted, the teazles are firmly held in place. The other rollers shown are for the purpose of securing the uniform tension of the cloth, and bringing the surface to be raised evenly against the revolving cylinder. The revolving scray *a* and the roller *f* with its oscillating arms are attachments whose function is to facilitate the revolution of the piece when the ends are joined together and it has become an endless web. The cylinder is usually run at about 150 rev. a minute.

In operation, the piece of cloth is slowly drawn through the machine in a direction opposite to that in which the cylinder is revolving. This is continued until the ends of all the loose fibres have been brought to the surface of the fabric, when the piece is removed, and again washed off and dried, as a preliminary to the first cropping or shearing process.

When the cloth is laid in the machine so that the cylinder revolves in a direction parallel with the warp or longitudinal threads of the fabric, the action of the teazles will be most effective upon the weft or transverse threads, which they will operate upon at right angles. It becomes questionable, therefore, whether the action of the raising-gig is as effectual as the hand process, and, at the same time, not more injurious to the durability of the fabric. It would appear that the successive operations of putting the latter through the raising-gig must greatly impoverish the weft threads, from the beginning the weakest portion of the cloth. On the contrary, the cross-raising of the hand process brings up the fibre from the warp threads equally as well as those of the weft. This difficulty is, however, almost obviated by a plan of passing the cloth over the cylinders in different directions.

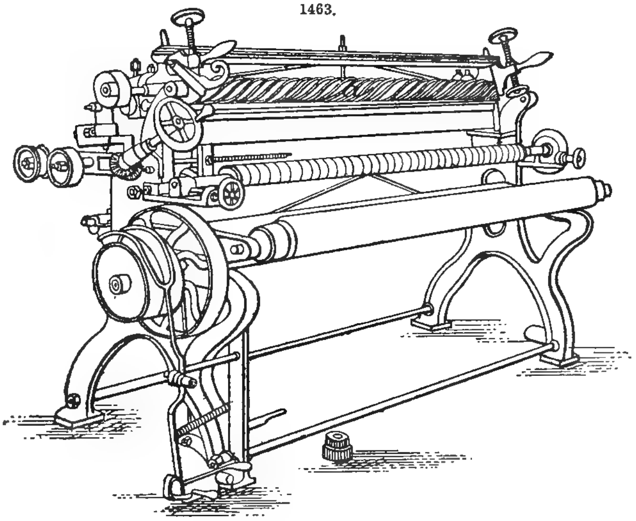
After working some time, the teazle-hooks fill with wool, or "flocks," as the fibres drawn out of the cloth are technically called, which impede their operation. The "rods" are then taken out, and the flocks are cleared out by children, the rods being replaced by another set in order to prevent the stoppage of the machine. Contact of the teazle-points with the damp cloth also impairs their efficiency, and renders it necessary to remove them occasionally for the purpose of drying.

All attempts to substitute metallic cards for teazles have only been partially successful, and as yet there is no likelihood of their superseding the natural article.

Cropping or Shearing.—After the cloth has been sufficiently long in the gig, it is with a little preliminary treatment of brushing next submitted to the operation of cropping. "Cropping" is the cutting of the raised nap (obtained on the surface by the last process) to a uniform level. Formerly it was done entirely by hand, but 60 or 70 years ago a shearing-machine was invented and introduced, after great resistance from the croppers. It has subsequently been much improved, so that it may ultimately be regarded as having quite displaced the hand process. Fig. 1463 is an illustration of the machine in its present state of development, as constructed in this country. It will be understood that there are many modifications of and various forms of it, though the radical principles of each are the same. The essential parts of the machine are the metallic cylinder *a*, into which, and passing helically around it, are inserted a number of steel blades; a straight piece of steel, called a "ledger-blade," fixed across the machine in close proximity to the "spirals," the revolution of the latter in conjunction with the straight blade forming cutting edges; an arrangement of rollers by which the cloth is brought against the cutting blades; and pile or setting-up rollers to raise the nap into the best position for the action of the cutting blades. In working, the long nap is brought against the ledger-blade, in which position the revolving cylinder cuts it down to the desired length. The cloth is passed two or three times lightly through, in order to secure uniform cutting.

The various parts of the machine require to be accurately adjusted, in order to perform its function properly. It is therefore usually made with compensating bearings, in order that, if unequal wear should take place, no defect in its working would result. This arrangement is applied to all the acting parts.

1463.

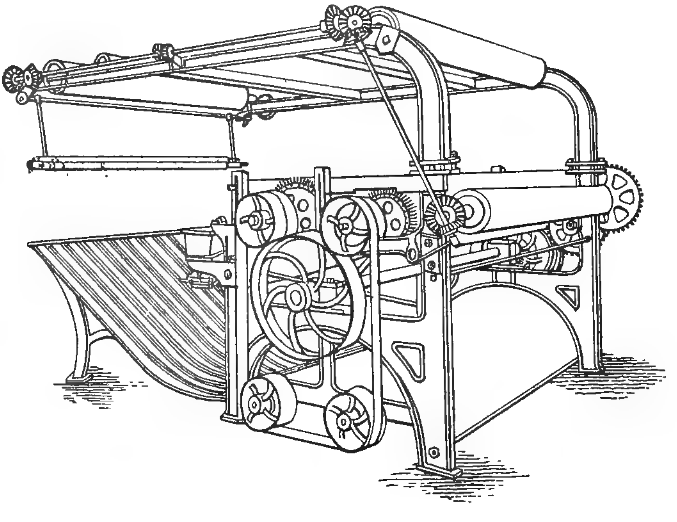


At the second raising, the cloth is damped and conditioned as before, and well raised, after which it is again tentered and dried as a preliminary to the second shearing.

This shearing is like the first, only requiring more care and a nicer adjustment of the piling-brushes and the cutting blades. The cloth must be gone over several times, and nicely cut each time.

After this, the cloth is generally submitted to a good brushing and steaming process, performed by a machine termed the "brushing- and steaming-mill." These mills are made either double or single, and with one or two brushes. Fig. 1464 represents a double brushing- and steaming-mill, with two brushes, one of 12 and one of 13 lags, and steaming apparatus having also a top and sloping scray.

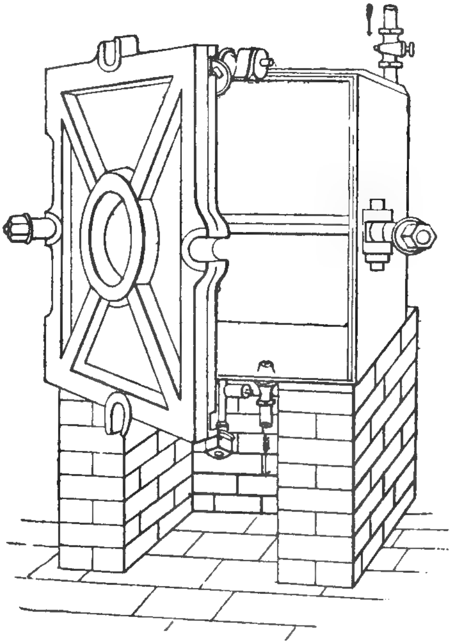
1464.



When the brushing and steaming is concluded, the cloth is ready for the first pressing. For this purpose, it is folded into regular lengths, glazed paper being introduced between the folds to prevent the faces of the cloth coming into contact with each other. Heated plates of iron, made hot in a steam-chest or oven (Fig. 1465), wherein steam is used at 30-lb. pressure, are then alternated with each end or piece, and the whole is subjected to severe pressure in a hydraulic press. When the cloth is removed, it is refolded in such a manner as to bring the creases of the previous folding opposite the flat faces of the press papers, by which arrangement they are removed at the second pressing.

Steam Boiling.—This succeeds the first operation of pressing, and has for its purpose the production of a permanent lustre on the face of the cloth. The cloth is wound tightly and evenly on round wooden or copper rollers, which have either a plain surface or are perforated with holes, the whole being covered with boiling-wrappers to prevent damage. Permanent and well-dried colours ought to be steam-boiled in a cistern full of water for about eight hours; then taken out and left to cool until the following morning, when the cloth should be wound from the first upon a second roller, by which process the part that was at the bottom before will be brought on the top. It should then be submitted to a second boiling for seven or eight hours. This ought to be repeated if necessary. Mixed shades and common colours should not be boiled or heated to a higher temperature than experience has shown they will bear without injury, which will be found to range between 49° and 82° (120°–180° F.); but they may be dry-steamed considerably higher in a box without water.

1465.



Several varieties of cloth manufactured from undyed wool, and intended for piece-dyeing are now at the stage of readiness for that operation. This includes the woaded or light blues, and several other colours. In piece-dyeing, it is requisite that the cloth should be kept well open and the reel constantly turned from the time the cloth is placed in the dye-bath until it is taken out again. If these details are neglected, the result will be a spotted and unevenly dyed cloth.

After the boiling and pressing has continued sufficiently long to fix the lustre of the cloth, it should be again put through the raising-gig, either in a wet state as before, or with steam applied to the face of the piece on the top of the gig, after which it should again be well washed with cold water, tentered, and dried. It is now sometimes "dry-beaten," or put through the raising-gig in a dry state, in order to loosen the nap for the last cutting process.

In the third and last cutting, especial care is taken that it shall be cut both very light and fine until the nap is reduced to the shortness required. After this, it is brushed on the dry brushing-mill, as a preliminary to the last burling and fine drawing.

Sometimes, instead of the last burling process, the web is inked with black or coloured inks. A machine has been invented to accomplish this process, and is meeting with increasing favour, especially in the case where cotton burls are numerous and require covering. It is adapted for any class of goods, the feeder of the inking-roller being regulated by means of a screw to take up more or less ink as required. After passing through the inking-machine, the fabric ought to be put once or twice through the brushing-mill without steam, and subsequently once with steam, which will greatly improve its appearance.

If burling is preferred, this should be carefully performed, all defects or holes being well drawn up by the fine drawer or mender, after which the lists should be wet and pressed with a hot iron to impart a smart finish.

Brushing and steaming on the steam-brushing mill now succeeds as a preparation for the second hot pressing.

This is a repetition of the previous pressing process, the cloth being again placed between heated press-plates, and subjected to pressure for 5–10 hours, after which it should be refolded and pressed again for a similar length of time.

If, at any of the preceding stages, satisfactory results are not obtained, the process should be repeated.

After having been well pressed, the finishing touch is now given by the cloth being polished with a moderate pressure of steam on the steaming apparatus or mill, which leaves the article in a merchantable state, only requiring making up for delivery.

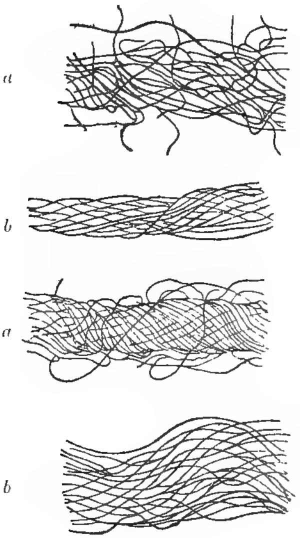
Cloth manufactured by the foregoing processes properly performed, and finished as directed, will be lustrous to the sight, soft and pleasant to the touch, and of a durable quality. The nap will be short and perfectly laid, so that dust will not penetrate it but lie on the surface, and admit of easy removal by brushing; it will not readily absorb water, neither will it shrink when wet, nor show rain-spots from a shower. When being made into garments, it will neither shrink with wet nor under a hot iron, and will long present a new appearance. When it begins to fade, the freshness can easily be restored by sponging and brushing.

Cloth is sold by the running yard, width is stated in inches, the substance is ascertained by the weight, and the quality by a gentle pressure of the hand of a competent judge when being drawn over the surface.

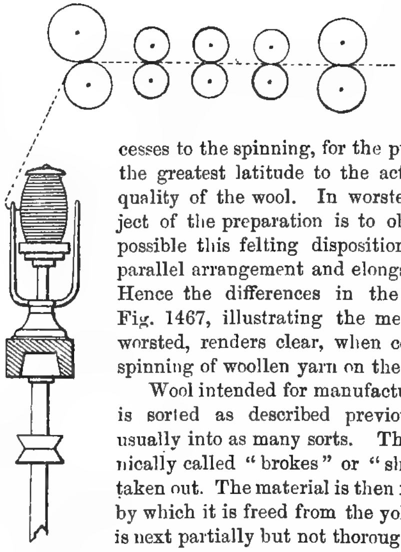
Worsted.—The second great textile industry founded upon wool as its raw material is the worsted manufacture. As observed previously, the wools of commerce are divided into two great classes: clothing wools and combing wools, otherwise short wools and long wools. The former at one time were almost exclusively used in the woollen trade, and the latter in the worsted trade. Owing, however, to the improvement in machinery that has been accomplished during the past 20–30 years, this distinction has to a great extent been obliterated. The invention and development of the combing-machine has enabled manufacturers to comb any free, firm-stapled, clothing wool, having a staple of 1 in. and upwards. Fine Botany yarns are now commonly spun and used in the worsted trade. On the other hand, combing wools are quite as frequently used in the woollen trade.

The essential distinction between woollen and worsted yarns (Fig. 1466) will be found in the arrangement of the fibres peculiar to each class of yarn. In the woollen yarns, *a*, the fibres are purposely entangled and crossed, and all drawing is avoided, in the preparation, in order to leave undisturbed the natural curvature of the fibre, and this arrangement is endeavoured to be preserved through all processes to the spinning, for the purpose of affording the greatest latitude to the action of the felting quality of the wool. In worsted yarns, *b*, the object of the preparation is to obliterate as far as possible this felting disposition, and secure the parallel arrangement and elongation of the fibres. Hence the differences in the processes, which Fig. 1467, illustrating the method of spinning worsted, renders clear, when compared with the spinning of woollen yarn on the mule.

1466.



1467.



Wool intended for manufacturing into worsted is sorted as described previously, though not usually into as many sorts. The short wool technically called "brokes" or "shorts" is carefully taken out. The material is then ready for scouring, by which it is freed from the yolk and grease. It is next partially but not thoroughly dried, as when being prepared for woollen yarn, often not being placed on the drying-stove at all, but simply put through the pair of squeezers or pressing-rollers as it passes out of the scouring-bath, whence it is conveyed to a carding-machine much like the scribbler or first carding-engine in the wool set. Here it is opened, cleansed, and carded, by which it is to a certain extent relieved from its grosser impurities as well. From this machine, it is doffed in the form of a rope sliver, and wound into a ball, for the supply of the combing-machine.

The first attempt to construct a mechanical wool-comber was made by Dr. Cartwright, the original inventor of the power-loom. This comber, though not much more successful than the same inventor's previous efforts, suggested the idea and formed the basis upon which succeeding mechanicians laboured to accomplish the end he sought. The first who made any decided advance upon it was Hawkesley, of Nottingham. His efforts were followed at a long interval—about 35 years—by the more successful attempts of Platt and Collier, which was a great improvement. A considerable number of these machines were adopted by manufacturers, and many have remained in use until within a recent date. In 1842, Donisthorpe made a further decided step in advance, and again in 1844.

The process of combing by hand, though it had been in vogue for ages, had several serious defects. The principal of these was that during washing the fibres got considerably entangled, and when the wool came to be combed, these crossed fibres would coil around the teeth of the comb when the wool was lashed into them, and which in fact it was necessary should be the case in order to secure its withdrawal and the combing of the portion under operation. When, however, the part left upon the holding comb came to be taken out, it was so firmly lashed around the pins that a great portion of the long fibres required to be broken in order to get it out, thereby increasing the quantity of "noil" or waste, and diminishing the "top" or best portion. The plans of all the inventors who worked at the problem of effecting combing by mechanical appliances were based upon this idea, regarding it as an essential element, and therefore in all their designs and achievements this serious defect reappeared.

Josué Heilmann, the French inventor of the celebrated machine known by his name, however, revolutionized this process of combing by the new principles he embodied in his invention. The essential parts of the important improvement are as follows. The framework contains two jaws, or nippers, through which the prepared wool is fed into the machine; when the fleece has passed sufficiently through, these close upon and hold it firmly. That part of the revolving drum which is armed with comb teeth then passes up and combs the end hanging out, the nippers holding the wool firmly and securely in this position whilst it is combed by the passing drum. In the forward revolution of the drum, the plain part of its surface passes up and presses against the uppermost of the drawing-rollers when they are in their uppermost position; at the same time it gathers up the cleaned end of the fleece, and passes it between the drawing-rollers. The upper roller is turned by the friction of the drums, and the lower roller by pressure from the upper roller, thus a tuft of wool is detached from the fleece, and again held by a second pair of nippers. As soon as the roller and drum have taken hold of the cleaned end, the first pair of nippers open, and, in the act of opening, press the fleece up into the teeth of the comb, at the same time that another comb is caused to fall into this fleece, and thus, as the tail end is detached, it is also partly cleaned by being drawn through these combs. The tuft is now entirely held between the two drawing-rollers, which, with their framework, are caused to travel down from their uppermost position to the lowermost one which they occupy, at a greater speed than the surface speed of the drum; the lower of the two drawing-rollers is then brought into contact with the plain part of the drum, causing the rollers to turn in a contrary direction, so bringing back the partly combed tail end of the tuft, which is held until it has received a second combing from the succeeding portion of the drum furnished with comb teeth; the rollers then deliver the thoroughly cleaned tuft and return into their former position to repeat the operation. A continuous sliver is formed by each succeeding tuft being so laid as to slightly overlap that which has gone before, and it is then passed forward into the can by the conducting-rollers. The card-rollers are for the purpose of brushing the noil out of the teeth of the drum, and this is pushed out of the teeth of the drum by a doffing-knife, and carried away by conducting-rollers.

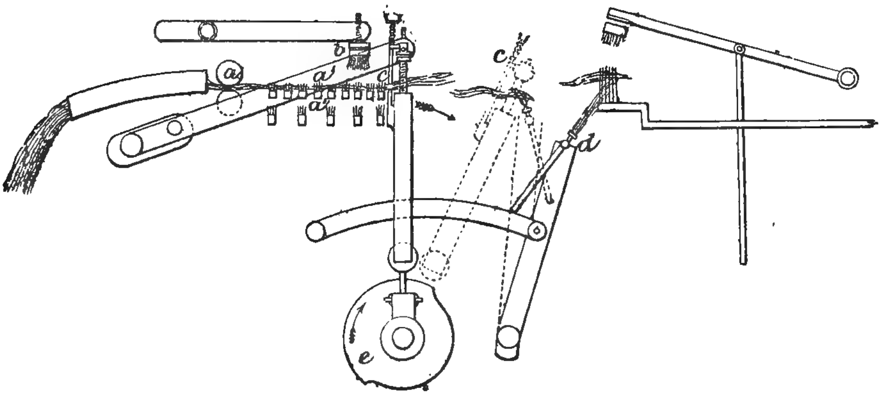
The introduction of the nipper principle into the combing-machine constituted a great advance over the preceding plans. Succeeding inventors therefore embodied it in their improvements, the result being that a great amount of litigation was engaged in before the rights of each could be clearly defined. Lister and Donisthorpe had invented a plan of combing wool, which, though accomplished by slightly different means, embodied Heilmann's principle; the consequence was that an action was commenced by the proprietors of Heilmann's patent, who secured a verdict in their favour. Lister thereupon made arrangements with them, whereby he secured the sole right of its application to wool-combing for the sum of 30,000*l*. This was done, not with the purpose of using the machine as made by Heilmann, but to secure the unmolested right to use and amend his own, which was considerably superior. Lister subsequently took out a number of additional patents, which were merely variations of the first, and intended only to prevent any colourable evasion though real infringement of his rights. Since 1852, when the purchase above mentioned took place, the machine as made and vended is said to have returned to the owner an immense sum of money.

The essential parts of the combing-machine as constructed by Lister & Donisthorpe are shown in Fig. 1468. The comber is combined with a screw-gill frame, the feed-roller *a* and the gill-bars *a a* of which, conduct the material into the machine, the tail end of each tuft of wool being combed as it is drawn from the last gill-bars The brush *b* descends and presses upon the fleece every time that the nippers detach a portion, to prevent it rising out of the pins. There is a pair of nippers *c*, the upper jaw of which consists of a broad blade with a sharp edge, which is a fixture, and the under one of an upright bar which is caused to slide up and down by the revolution of the tappet *e*; this under jaw has a grooved surface, into which the edge of the blade is inserted at each nip. A carrier-comb *d* takes the tuft from the nippers, and places it upon or rather in the teeth of the circular receiving-comb *f*, of which only a section is shown. A brush *g* drops into the points of the teeth, and presses the tuft down into a proper position for being drawn off. The illustration shows the nippers in position to detach a tuft from the gill-bars; when they have closed upon it, the framework in which they are held is made to traverse the arc of a circle into the position shown at *h*; there the carrier-comb advances to the same position, and pushes its teeth into the end of the tuft, just as the nippers open to release it; the carrier then passes away from the dotted position, and, in those to which it passes, transfers the tuft to the receiving-comb. The portion deposited here is drawn away in a continuous sliver, and, as it is the dirty end or noil which is placed upon the circular comb, this is cleaned by being drawn off, the noil left being removed in the usual way by a knife-lifter and conductor-rollers.

Numerous improvements have since been made in the wool-combing machines, but all have been based upon the inventions of Heilmann and Lister & Donisthorpe. It is unnecessary to trace these further, as the principle will be thoroughly understood from what has already been stated. Fig. 1469 is a perspective view of a wool-comber which is highly esteemed in the trade.

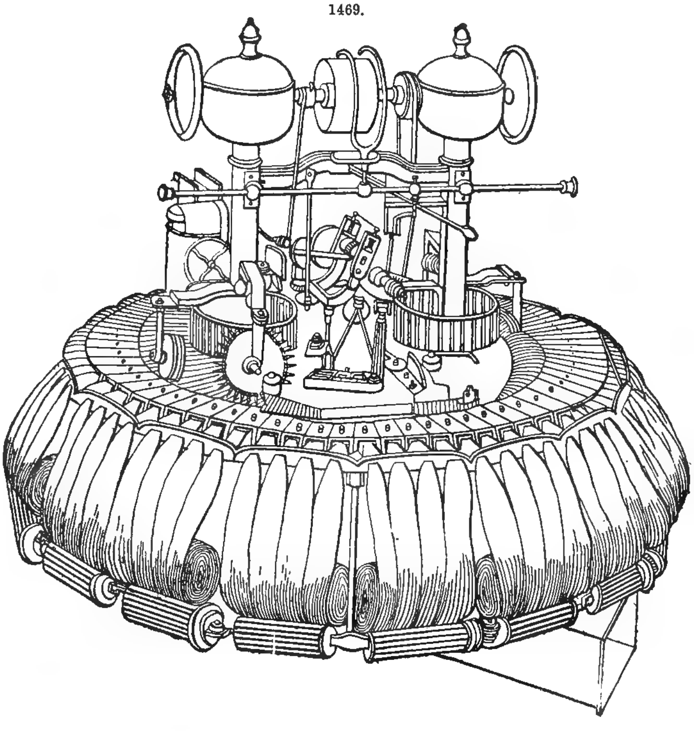
The introduction of mechanical combing has been a main cause of the great development of the worsted trade, as a single machine will comb a greater quantity of wool than 100 men could do by hand, and that in so much better a manner in every respect as to make it exceed the hand process as much in quality as it does in quantity.

1468.



Drawing.—The process of drawing is partly intended to complete or perfect that of combing, namely to secure the parallel arrangement of the fibres of the wool, and to take from them their wavelet or undulating form, and, by elongating the fibres in that manner, to secure the greatest length. This is accomplished by the application of heat in the drawing processes. The sliver is also attenuated and reduced to fit it for the spinning process.

1469.



The "set" of drawing machinery usually consists of 6 frames or screw-gills. The screw-gill drawing-frame is composed of an iron reservoir or steam-chamber placed in advance of the feed-rollers, the latter of which deliver the sliver to a series of gill-bars which travel from the feed-rollers in the grooves of two screws laid parallel to each other. These gill-bars are furnished with two or three rows of pins. When they have arrived at the end of their traverse, they drop into the grooves of two other parallel screws arranged below the first pair for their reception, and by which they are carried on their return to a point below that from which they started, when they are elevated into the first position by the action of two cams, one on each screw. The screw-gill drawing-frame being fully described in the article (see pp. 1180–1) on Jute Manufactures, the reader is referred thereto for fuller particulars. The differences are in points of detail merely, occasioned by the respective natures of the material they are constructed to work. The steam-chamber is one of these.

As soon as the slivers leave the combing-machine, a given number, say about 16, are placed upon a feed-table and divided into two sets, each of which is passed first over the heated chamber by which the slivers are softened and better adapted for the drawing process, then through two sets of coarsely-fluted rollers which serve as feed-rollers. As the wool is delivered from these, the gill-bars rise, and the pins entering it conduct the material to the drawing-rollers. These rollers move with a velocity considerably greater than the feed-rollers, say 5–6 times or more, taking the wool from the latter in an even and regular manner; and attenuating the combined slivers from their original volume by as many times as the drawing-rollers exceed the feed-rollers in surface velocity. The several drawings are passed into a coiling-can, by which they are loosely twisted into one. Eight of these drawings are next passed through the second frame, and elongated in the same manner, the process being repeated a third time. In the fourth passage through a similar machine, the material is received and wound upon two bobbins, carried upon two large spindles, having large fliers, by which the drawing is slightly spun or twisted, after which it is called a "slubbing." In the fifth frame, the travelling gills are replaced by four sets of rollers, through which the wool is passed, 16 slubbings being arranged in sets of 4, each set being further attenuated, slightly twisted, and wound upon four bobbins. The sixth is the last and finishing process of drawing. In this, three of the slubbings from the last frame are again attenuated, twisted slightly, and wound upon bobbins as before.

The set of drawing-frames thus consists of 4 gill-boxes, the last of which delivers its material in spindles, and two roller drawing-frames, which receive it in the same manner.

Roving.—The "slubbing," having been sufficiently prepared, is ready for the roving process. This is simply a further attenuation of the coarse and loosely-twisted strand of wool to fit it for spinning. In this set, there are again 6 machines, all alike in principle, each doubling and delivering the preparation finer than its predecessor. A slight twist is imparted in each case to secure cohesion. After having passed these machines, the roving is sufficiently reduced, and yet possesses strength enough to pass into the next stage without parting asunder.

Spinning.—Spinning is the last process in the formation of the thread, and in worsted is performed on the continuous principle by the throstle or cap-spinning machine. This is constructed on the same principle as the preceding machines, only differing in the parts being smaller and the spindles more numerous. The latter are vertical, and rest in a footstep-rail having a bolster or bearing-rail fixed above the wharve. A traverse-rail which carries the bobbins is made to ascend and descend by means of a heart-shaped cam. This traverse enables the yarn to be laid upon the bobbins in even layers. Each spindle is mounted with a flier or cap, the former having curls at the extremities of the flier branches. The rovings are conducted from the creel between two rollers, the lower of which is longitudinally fluted; next through or between three pairs of carrier-rollers, which simply bear the rove to the front or drawing-rollers, by whose accelerated speed it is finally attenuated. Being attached to the bobbins upon the spindles, the twist or twine is put in according to requirement, a given number of turns to the inch, which is easily regulated by a change pinion. For 30's yarn, there are usually about 10 turns per inch. (See Fig. 1467, p. 2088.)

Worsted weft or filling is mostly spun upon the pirns, ready for the shuttle of the loom; whilst warp yarns are spun upon the flanged bobbins, from which they are wound and warped in a manner scarcely differing from the processes of the cotton trade. There is, however, only a small quantity of worsted yarn used for warp purposes, as, since the introduction of cotton warps, these have been (except for special purposes) almost universally adopted. They consist of good 2-fold yarns, the bulk of which are spun and doubled in the Bolton and Oldham spinning districts of Lancashire.

The system of spinning worsted, thus briefly outlined, is that known amongst practical men as the English system. For half a century, the trade of the worsted manufacturing centres of this country, based upon this plan, has been conducted with uninterrupted progress and prosperity. Of late years, however, owing to a complete change in the current of fashion, which has been diverted to softer fabrics capable of conforming more easily and gracefully to the outlines of the female figure, worsted goods as hitherto produced in this country have been much neglected, especially for costume purposes. The consequence has been a great decline in the demand, unprofitable trade, and diminished employment for the work-people. The return of worsted fabrics to public favour has been anxiously waited for, but without success. This adverse state of affairs has induced much discussion, and has brought into prominent consideration the advisability of adopting the French system, by which fabrics are produced very much better suited to present requirements. The chief cause of hesitation seems to be a prevalent doubt as to whether the taste of the public is more than temporarily alienated from fabrics produced on the English system, and whether the investments necessary for a change to the French plan might not prove a total loss. There are persons who assert that the change of fashion is not in the direction of good taste, nor in harmony with those natural principles that underlie the art of dressing. Others again dispute this conclusion, and believe the opposite, and that the change of fashion marks a decided advance in the recognition of true principles, and as a consequence it will be perfectly futile to hope for the return of Yorkshire worsted fabrics to popular favour. To this view the writer inclines. From these statements it will be obvious that any change will for a time at least not be more than partial, and that success on the part of the pioneers of the movement will have to be assured before the step becomes anything like general.

The radical difference between the English and French systems of spinning worsted lies in the fact that all the processes of the preparation are conducted without twist being imparted to the material, and that the spinning is performed on the mule-frame in place of the throstle. Another important point of divergence is, in some instances at least, in the French plan the wool is worked dry, that is without oil, but this is not to be recommended. Starting also with a softer staple of wool, all these differences are in favour of the production of a soft fabric, that will drape easily and gracefully, and so meet the present requirements of the *modiste.*

When the fact is considered that the wool fibre is covered with scales, it will be apparent that to twist them together in the preparatory stages, in which a great deal of doubling and drawing has to take place, can hardly be a wise proceeding, as the scales are sure to interlock with each other, especially when insufficiently lubricated, the consequence being that when the drawing takes place the fibres are strained and to some extent broken, whilst a hard and wiry yarn is the product. By the plan of avoiding twist until the spinning stage is reached, the drawing is rendered easier, less waste results, and a softer yarn is produced, which is more bulky in relation to the weight.

With the object of aiding the introduction of this system into this country, an eminent firm of machinists has paid great attention to perfecting a series of machines for the English market, by which yarn can be spun on the French system. The initial stages for several steps are alike. After they begin to diverge, briefly described they are as follows:—

1st Process: *Carding.*—In the carding-engine, the undried wool from the washing-machine is carded. It is spread by hand upon the feed-lattice, whence it passes through a pair of feed-rollers and successively into contact with three burr-rollers, the first of which is 18 in. diam. and steam-heated, the second 9 in., and the third 12 in., each having guard rollers and boxes for the reception of burrs. The burr-rollers are covered with steel teeth. This triple arrangement is an improvement upon the single-roller system. The clothing of each differs from the preceding, being graded from coarse to fine; the effect is that the first roller throws out the coarse, large burrs; the second, those of medium size; whilst the third cleans out the finest burrs, seeds, &c. An oiling apparatus is fixed so as to discharge its contents on the wool at this stage, when oiling is held to be desirable. From here, the wool enters into the breast, the cylinder of which is 36 in. diam., and is provided with three pair of workers and strippers, respectively 8 and 3¼ in. diam. There are two swifts, each 50 in. diam., with a complement of four workers and strippers of the same dimensions as those above, fancy and stripper, and angle stripper. The sliver is stripped and balled by a calender-delivery and balling-head into balls 16 in. long.

2nd Process.—7 balls from the carding-engine are put into the screw-gill balling-machine, and doubled into one with a draft of about 5. The object is to straighten and draw the fibres into parallel order more perfectly. The machine has one head of one delivery, gill-screws to carry 12 gill-bars, and balling motion with surface rollers.

3rd Process.—The balls from the preceding machine, to the number of 10, are next supplied to the screw-gill lap-machine, the function of which is to reduce the round slivers of the balls to a flat sliver or lap, to suit the combing-machine, which comes next in order. It has one head of one delivery, fluted rollers back and front, and screws for the same number of gill-bars as the preceding, the fallers having brass gills double pitch, and the rollers weighted with racks and friction-pulley.

4th Process.—Combing is performed on Little & Eastwood's patent combing-machine, which is a very compact and highly efficient machine, nearly all the working parts being placed inside the circular comb of about 40 in. diam. The gill-head is put within the circular comb, and is fitted with 8 gill-bars. Inside the circular comb is a cylinder, around whose circumference 6 pairs of nippers are arranged. A stripper removes the noil, and a stop-motion arrests the action of the machine when the sliver accumulates on the drawing-off rollers. Its action is as follows: The wool is fed into the fallers of the gill-head by feed-rollers having an intermittent action; the end of the lap is seized and held fast by a pair of nippers on the cylinder, while the feeding head recedes and draws the wool through the teeth of the fallers, combing one end of the tufts by this operation. When the lap is nearly pulled apart, a spring divider thoroughly separates it, leaving a tuft of combed wool in the nippers on the cylinder. The revolving cylinder next carries the tuft over and deposits it on the pins of the circular comb, the uncombed portion or noil ends being left inside the circle behind the pins; this end of the wool is then combed by being drawn outwards through the teeth of the circular comb by means of the drawing-off rollers. As the circular comb receives the tufts of wool with one end combed, the whole of the noil being placed behind the pins, its action is quite free, and little strain is put on the pins; the brushes and drawing-off leathers have diminished work; the fibres of the wool are better preserved; and the wear and tear of the working parts is reduced to a minimum. This structure of machine possesses great capability, being well adapted for Australian, Cape, River Plate, and similar wools. It is especially suitable for short wools, and in long wools will comb up to 6–7 in. in staple. Its delivery is arranged to double three into one: that is, as the sliver from the drawing-off rollers is delivered into the can, it may be so set as to take one or two other slivers along with it. In the combing process, therefore, with drawing three into one, the drawing after passing through the comb is altogether nine into one.

5th Process.—In this, nine slivers from the comb are combined in one by means of the screw-gill balling-machine, the draft being about four. It presents no important features of difference from the one described before, except being doubled, having two heads of two deliveries each, two sets of gill-bars, and brass gills of double pitch. All these particulars can be varied according to requirement.

6th and 7th Processes.—The sixth process is that of back-washing. In the English system, it is regarded as desirable to wash and clear the wool before reaching the comb, whilst in the French plan this is deferred to this point. The back-washer contains two washing-troughs, each fitted with two immersion-rollers; two sets of squeezing-rollers, and five copper drying-cylinders. It has one head of two deliveries, with front and back rollers fluted, screws for twelve gill-bars, balling motion, and creel for eighteen balls. The wool leaves this process thoroughly cleansed from oil and earthy discoloration, and is further drawn and straightened. It works with a steam pressure of 5–10 lb. a sq. in. in the drying-cylinders, which are without bearings on one side to permit of the wool being easily passed over them. It will efficiently wash and ball 800–1000 lb. of wool in a day.

8th and 9th Processes.—Repeated passages through the screw-gill balling-machine, as described in the 5th process, after which it is ready for the next stage.

10th Process.—This is the first process of drawing. In it, the sliver-balls are brought from the last machine, and are doubled two into one with a draft of about four. The slivers first pass through feed-rollers, then over a porcupine-roller, next between a pair of front rollers, whose speed being greater than that of the porcupine, the fibre is drawn and straightened through the teeth of the latter. After this, it passes between "rubbers," which carry it forward and deliver it upon a bobbin actuated by a calender-roller. The machine contains eight porcupines and eight pairs of rubbers, and balls the material on four bobbins 14 in. traverse, two threads upon each, and each of which is reduced from two balls, requiring therefore 16 balls in the creel. It can be made for six, eight, ten, or twelve bobbins if required.

11th and 12th Processes. Second Drawing-frame.—Repetitions of the preceding operation, and on a similar though rather smaller machine. The sliver from the foregoing is doubled two into one with a draft of about four, as in foregoing operation. The bobbins in this case are of 12½-in. traverse.

13th Process. Reducing.—Again a process similar to the last. The slivers are again doubled two into one, and attenuated by a draft of four, by which they are again reduced to half their former dimensions. The machine has four boxes, eight porcupines, eight pairs of rubbing leathers, eight bobbins of 7-in. traverse, and creel for two heights of bobbins.

14th and 15th Processes. Slubbing.—Both similar to the preceding, but the doubling is four into one, with a draft of four, giving sliver of the same dimension. Bobbins 7-in. traverse, two threads being wound upon each.

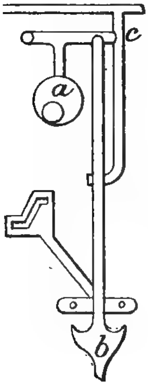
16th and 17th Processes. Roving.—Substantially the same as the foregoing, and performed on the same class of machine, though somewhat smaller. Doubling four into one, and drawing four.

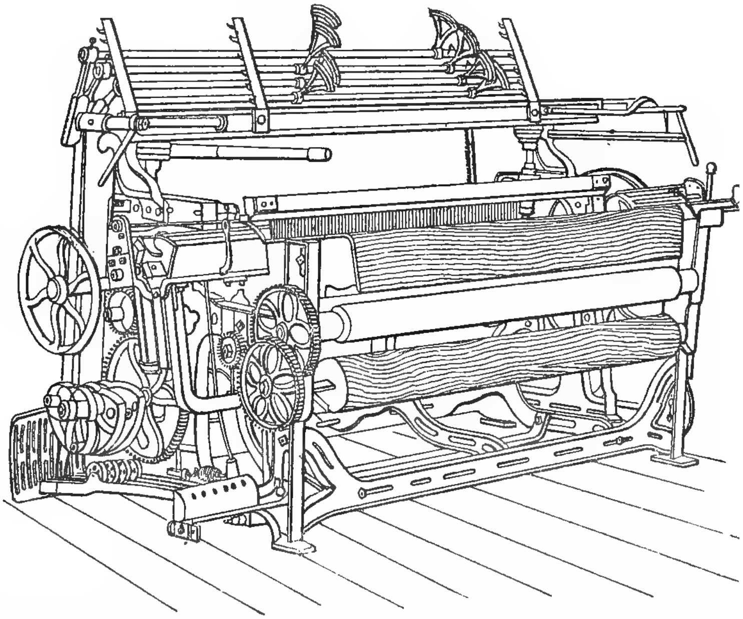
18th Process. Finishing roving.—This is the last stage of roving, and again the machine is similar to the preceding. The doubling is however two into one, with a draft of four. This last machine contains four boxes, eight porcupine-rollers, eight pairs of rubbers, and creel for four heights or 16 bobbins. The finished roving is received on eight bobbins of 7-in. traverse. The machines for all the preceding processes from and including the tenth, are similar in construction and principle, varying only in size and very slight details; the latest ones are smallest. To secure freedom from vibration, which would injuriously affect the quality of the processes, the head-stock is built upon a strong base-plate, which prevents vibration from the gearing and the rubbing motion. The different parts are so constructed as to permit changes to be made with the greatest facility, to secure steadiness in working, so as to prevent any cutting of the wool, and finally to obtain durability in the machine. Through all the preceding stages, there has been no twisting of the fibres, consequently no straining or damaging of the fibre, either by destroying its elasticity or injuring its scaly imbrications. It arrives at the stage in which it has to assume its final form with all its qualities intact, and in the best condition for being subjected to severe torsion and the strain of a great draft. A four-hank roving is drawn and twisted simultaneously by a draft of ten, so as to make a yarn of 40's count.

19th Process. Spinning.—The final machine of this series is the mule, and, not as in the English system, the throstle-frame. Platt Bros. & Co., Limited, of Oldham, the makers of the different machines thus briefly described, have introduced several important improvements in this machine. The one attached to the series of machines under notice contained 300 spindles 16 in. in length and $\frac{11}{16}$-in. gauge, and was fitted with four lines of rollers, the lower one of each line being case-hardened, and the front top rollers being of wood covered, and having case-hardened iron pivots, weighted by saddles and levers, the three rear-line top rollers being simply incumbent upon the lower ones; it had also the double rim-band arrangement, and conical friction-box for working the cam-shaft and taking in the scroll-shaft. By newly invented appliances, the carriage can be stopped, or rather will be stopped automatically, at any point of its course, either in coming out or going in, by the presence of any obstruction, and the spinning operations will cease automatically should the cam-shaft make its change before the appointed time. New means are adopted for regulating the tension of the backing-off chain during the depression of the faller-wire to the spindle-point, preparatory to commencing the backing-off. An automatic arrangement for forming the upper cone of the cop, technically called a "nosing" motion, is included in the various improvements, and also a patent winding-on motion, by which the winding is automatically adjusted to the enlarging form of the cop. These improvements constitute this mule not only a novelty for spinning worsted in this country, but also a more perfect machine for its purpose than any existing upon the Continent from which the general idea has been borrowed. Many of the novelties have been transferred and adapted from the cotton-spinning mule.

Weaving.—Passing the intermediate processes after spinning, as not differing in any feature of importance from those in other divisions of the textile trades, we come to weaving. Here again there is little to distinguish it from the same branch in the cotton trade, to which it bears a close resemblance in details. There are a great quantity of fabrics made in a plain weave, though not to such a proportion as in cotton. In the worsted trade, the complicated weaves are proportionately much more abundant, and the jacquard a far more frequent adjunct of a loom. The plain loom, as it is called, is usually fitted to weave orleans, alpacas, mohairs, and twills up to 6–8 shafts.

1470.





About the first departure from this class of loom is the one represented in Fig. 1470. It is a single-pick rocking-box loom, with a two-holed shuttle-box, and weft motion at each end. The cylinder and boxes are on the ordinary plan, but a tappet *a* is introduced upon the top or single-pick shaft, which elevates a rod having a double-catch *b* at its extremity, connected with a slot motion working in the inclined slot-groove. In this groove works a single stud, projecting from a horizontal square rod placed parallel with the bottom shaft. At each end of this rod is fixed a clutch, which can slide the tappet backwards and forwards on any single pick whenever required as directed by the arrangement of the cylinder. Three levers are provided on the cylinder, the middle one working the tappets, the inside one the boxes at the cylinder end, and the outside one the boxes at the driving end, the motion being transmitted through a small rod in proximity to the spur-rail.

1471.

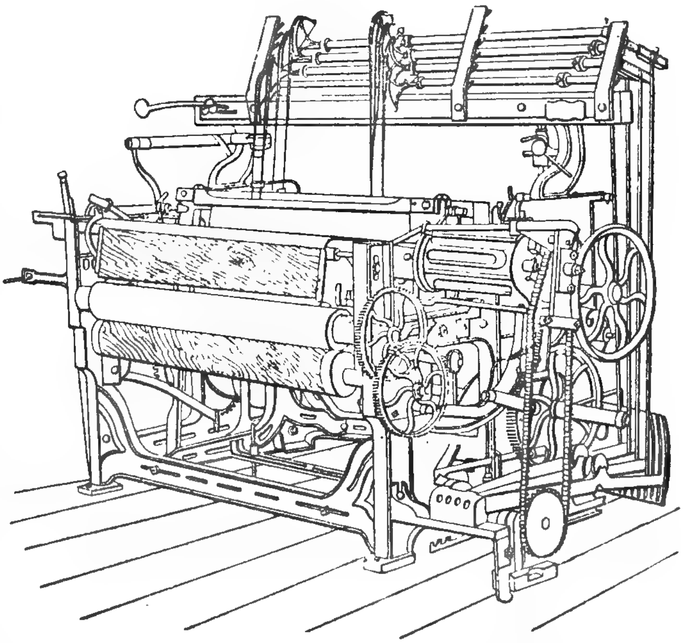


Fig. 1471 represents a loom constructed for a wider range of work than the preceding, being adapted to weave complex checks requiring a variety of colours. Its treading or shedding arrangement is similar to the preceding, but differs in its box capacity, 6-8 or more boxes being arranged around a common centre, and caused to revolve by an endless chain from a star-wheel in connection with a pegged-wheel actuated by a three-rise tappet on the bottom shaft. A card motion having an eccentric and ordinary cylinder connects this tappet with the catches. A novel arrangement, however, is introduced into this loom in the shape of a sliding bowl between the three-rise tappet and the upright lever that moves to every double pick, and draws the drag catches that pull round the boxes. This sliding bowl is actuated by the cylinder, which slides it backward and forward to or upon any of the elevations of the three-rise tappet, as required, two cylinder pegs of different lengths being used to effect this object. The movements can "skip" or pass over any of the shuttle boxes, according to requirement, with facility and ease, so as to bring any desired shuttle into work. The complicated mechanism of this class of looms has been within recent years brought to great perfection, thus giving certainty of action and relatively great speed.

Into the finishing processes of this branch there is no necessity to enter.

Carpet (Fr., *Tapis*; Ger., *Teppich*). The carpet manufacture forms a considerable branch of the worsted section of the textile industries. Floor-coverings are of great antiquity, and in general use amongst both savage and civilized races. They were most probably suggested by the verdant clothing of the earth's surface, and consisted in early times of leaves, grasses, rushes, straw, and similar substances of vegetable origin. Amongst pastoral races and those addicted to hunting, the skins of domestic animals and of those slaughtered in the chase were at an early time utilized in the same manner. It is not improbable that the art of weaving had its origin in the endeavour to obtain a cleanly and more comfortable article than leaves and rushes. This was realized by plaiting or interweaving reeds from the river-bank in a manner which has survived to this day. In tropical climes, and the warmest of the temperate regions, these woven mats are still extensively used; especially amongst the poorer classes of society. With the development of the art of weaving, more luxurious coverings were devised, for which a ready demand was found amongst the rich. Ancient civilized nations very early attained great skill, and displayed a high degree of refined taste in the designing and manufacture of carpets. China, India, Persia, Turkey, and Spain, under the Moorish dominion, are stated to have attained excellence in this respect. According to accepted canons of taste, the work produced in Hindoo, Persic, and Turkish looms, yet stands in the front rank, if not in the very first position for its indisputable elegance of design and quality of product. Of late years, however, it is complained that these characteristics are undergoing deterioration, as contact with European peoples is degrading the former, and making the artistes acquainted with the processes of sophistication.

Coming to the present times, it need only be remarked that as carpets are articles of general consumption in all civilized countries, their manufacture is very widely spread. In this country, Kidderminster stands at the head of the districts where the industry is carried on; Wilton, Worcester, Rochdale, Halifax, Dewsbury, Durham, and several towns in Scotland, also participate in the trade. The Continent receives a large portion of its supply from the looms of England, though factories exist in some countries there in which high-class fabrics are produced. Of late years, a great development has taken place in the carpet manufacture of America, stimulated by the prohibitive tariff that has been applied to foreign productions. Philadelphia is the centre of the American carpet industry.

Carpets are made of various materials, either unmixed or in different combinations, according to the structure or effect required. A common carpet is produced in jute by the employment of dyed yarns, the effect being obtained by arranging the colours in stripes parallel with the length, a checked effect resulting from crossing these with various coloured wefts (transverse threads). The "Kidderminster" or "Scotch" carpet, as it is indifferently called, is a figured fabric, generally having a worsted warp and a woollen weft, though in low qualities the latter is sometimes of cotton. In tapestries, Brussels, and similar fabrics, the warp is of linen or cotton, and the filling or weft forming the back of cotton or jute, whilst the pile is invariably of worsted.

Until within a comparatively recent period, carpets were woven in hand-looms, but the growing demand and the progress of invention has led to the introduction and extensive adoption of power-looms in this as in all the other textile industries. The different varieties of carpet, however, require different kinds of loom. Fig. 1472 is a representation of one of the best looms for the production of Scotch or Kidderminster carpets. As a great portion of the effect is obtained from the employment of coloured wefts, the loom is fitted with revolving shuttle-boxes, which permit of the employment of as many as 16 shuttles, each containing weft of a different shade or colour. Another important feature in it is the possession of a double-beat lay, produced by the action of a cam, and which enables a clear shed for the passage of the shuttle to be secured, and, the weft being driven closely home, a firm texture is obtained. An improved arrangement for taking up and retaining the fabric as it is produced is introduced, ensuring uniformity of texture. There is very little in this machine in the way of specialities beyond what has been described in preceding articles on the different branches of the textile industries, except the few adaptations needed to render it better suited for its particular purpose. One feature, however, which has not hitherto been described, and which is a chief purpose of its introduction, is the jacquard attachment, a most important adjunct to the loom in nearly all the textile trades.

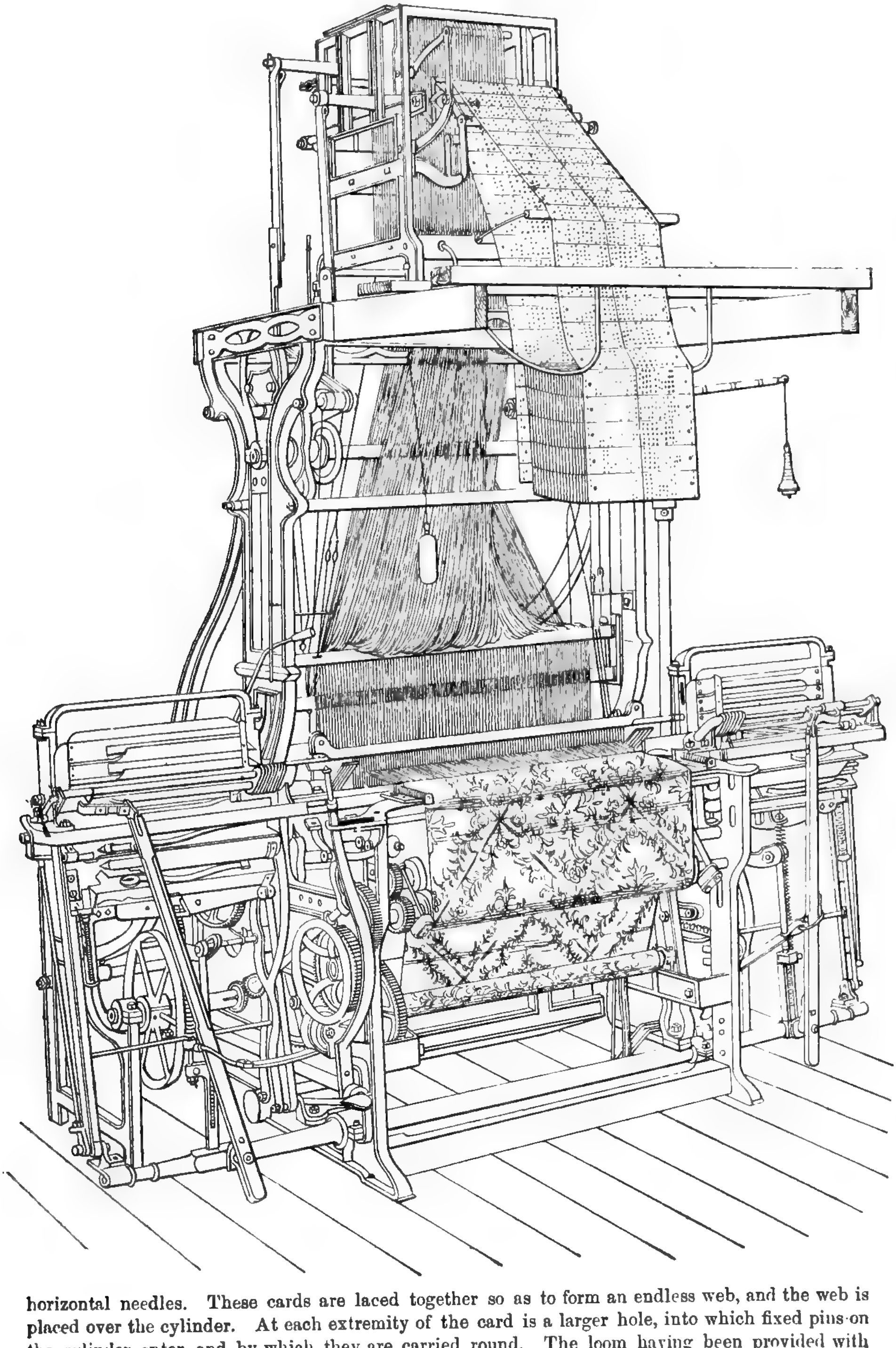
Figured fabrics have been produced in the loom for ages past, but these required great skill on the part of the weaver to fabricate, and were consequently rare and costly, until the invention of mechanical aids to the weaver. These aids gradually increased in number, and were of various degrees of merit. The most important, and the one in general use until about 1820, was the draw-loom, which required the weaver to have an assistant, called a "draw-boy." The boy was afterwards partially superseded by the invention and adoption of a machine called a "draw-boy machine." These plans were in common use some time after the invention of the jacquard, but the great superiority of the latter when its merits become known, quickly secured its adoption. It is simply a development of the draw-loom.

The jacquard machine was introduced into England about 1820, and after that time was soon extensively adopted. Numerous improvements have since been made by different persons, and it has been brought to a high degree of perfection. It was first applied to the hand-loom, and after some time to the power-loom. Its capacity was greatly extended by the invention of the system of making compound harness, and also "split" harness, by two weavers of Bethnal Green.

A brief description of the illustration will suffice for present purposes. The mechanism contained in the frame on the top of the loom, and which constitutes the jacquard, consists of a prismatic roller called the "cylinder," which revolves on its axis. Inside the frame near this is a perforated board, called the "needle-board," containing a considerable number of "needles," usually 200, 400, 600, or 900, and from these numbers the jacquard is named. It is not often that in the power-loom this number exceeds 400. These needles extend horizontally across the frame, one end protruding about ¼ in. through the holes in the needle-board in the direction of the cylinder, whilst the other terminates in a box on the opposite side of the frame, called the "spring-box," because each needle at this extremity is fitted with a fine spiral spring, the whole of which are contained in this box. In the centre of the length of these needles, a loop or eyelet is formed, through which wires are vertically passed having hooks at both extremities, the lower ones being attached to the descending cords called the harness, which again are connected with the leashes containing the mails or eyelets in their centre, through which the warp threads horizontally pass. The tops of these wires are bent to form an acute-angled hook, almost like the barb of a fish-hook

Above these hooks, is a frame composed of several bars, called the "griffe," which is made to ascend and descend alternately, the bars fitting into the angle of the hooks. The "cards" are strips of cardboard about $\frac{1}{8}$ in. thick, closely perforated with round holes to receive the ends of the horizontal needles. These cards are laced together so as to form an endless web, and the web is placed over the cylinder. At each extremity of the card is a larger hole, into which fixed pins on the cylinder enter, and by which they are carried round. The loom having been provided with

1472.

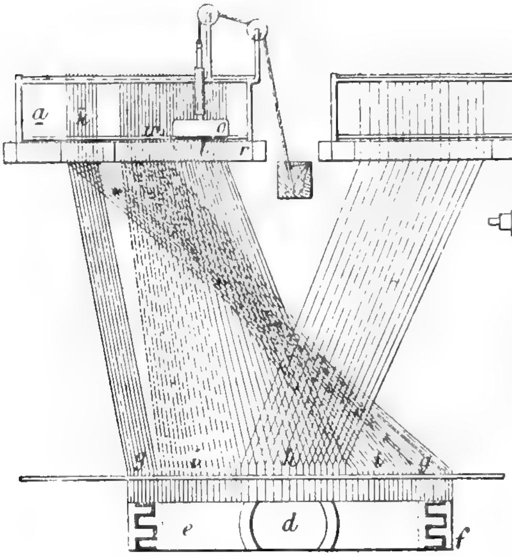


warp, and the proper connections established between the different parts, it is ready to commence work. The cards are perforated to produce the design required, and according to this the pattern is woven. With the commencement of weaving, the card cylinder begins to revolve, bringing up the cards on the inside of the jacquard-frame. The cylinder being carried in a "lay" or batten, oscillates a sufficient distance to allow space for it to be drawn or pulled round by a pawl or lever, by which it is moved. Every movement is the fourth part of a revolution, and brings up a fresh card upon the cylinder, at the same time delivering the most advanced upon it. The cards are so adjusted that each lies evenly on the flat surfaces of the cylinder, and by the oscillation of the batten is brought "square on" against the needle-board. The ends of the needles, projecting about ¼ in. through the board towards the cylinder, enter the perforations of the cards if these happen to be opposite their extremities, and are thus undisturbed, and keep their hooks upright. The griffe having simultaneously descended, its bars catch hold of these hooks, and in rising it draws them upward, and through the harness and the leashes containing the mails lifts the warp threads, opening a "shed" or passage for the shuttle. As only a portion of the threads are required to be raised at once, the others are prevented rising by the following means: When the cards are pressed against the needle-board, those needles which do not come opposite a perforation or hole in the card are pressed back and carry with them their vertical hooks, which are thus pushed out of range of contact with the bars of the griffe. Owing to this they are not drawn up when the griffe ascends. The threads thus left down are usually, though not always, lifted by the succeeding card. It will thus be obvious that there is scarcely any limit to the capacity of the jacquard to produce variety of design, as any single thread of the warp can be raised when required. In the ordinary jacquard, one card is required for every transverse thread or pick of weft contained in the figure or design of the cloth. When these have all passed over the cylinder, the pattern is completed, and a repetition commences. Sometimes these designs are very elaborate, and take many thousands of cards, instances having occurred in the silk and linen trades wherein they have exceeded 30,000. Many ingenious appliances have been invented to diminish the number needed in such cases, but to detail all these is not necessary; a description of one of the most recent improvements will suffice.

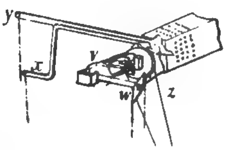
This is an invention patented during 1881 by James Irving, manager for Richardson, Tee, Rycroft, & Co., linen manufacturers, of Barnsley, and which is intended to obviate the necessity hitherto existing of having to change the set of cards in use when weaving goods having end borders or figured centres, or both. The common plan would be to use a sufficient number of cards to work the design right through, but as the use of a great number of cards can be dispensed with by employing one set for the centre figure or border or both, and another set for the ground and end border, and making the change when required, this plan is generally in use. The great drawback to it has been the cost of making the changes, weavers (men) being paid 1–2*d.* for each occasion. This generally amounts to 3*s.*–5*s.* per loom per week, an important addition to the cost of weaving. Where women weavers are employed, it has been necessary to employ a man or two for the purpose of making the changes for them; but as many of these requirements arise at the same moment, much additional time is lost in waiting. In whichever way the changes are made on these plans, 10–15 per cent. of the working hours of the week are lost. As fabrics which require these changes are numerous in all the textile industries, Irving has conferred a service on the trade generally by this invention.

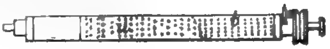
In his first plan, to the ordinary jacquard with which the loom is furnished, he adds a supplementary apparatus of the same kind, which is provided with all the requisites as in the first case, but is smaller. The conjoint apparatus stripped of all unnecessary detail is shown in Fig. 1473. The first jacquard is represented at *a* and the second at *b*. The connection between the two sets is secured by the harness descending from *b*, and joining the harness of the first jacquard at *h*. In the figure, it is assumed that the fabric in process of manufacture is a rectangular drugget, or other article having a central design, which is indicated by *d*, a plain or ornamental ground *e*, side borders *f*, and cross or end borders not shown in Fig. 1473. The lines marked *g h i* indicate the mails, of which, to preserve clearness, a few only are introduced. The mails *g* lift the warp threads, which enter into the formation of the borders, being attached to the hooks of the set of needles at *k*, which are operated by a set of border-pattern cards, shown on the cylinder below them. The mails *h* lift the threads that enter into the composition of the central figure, and are connected with a set of needles at *l*, and also by the additional harness to the needles in the second apparatus. The mails *i* operate the threads that compose the ground which are not woven either into the side borders or the central figure. These are connected with a set of needles at *m* by means of the harness indicated by dotted lines. Above the needles *l*, a plate *o* is suspended, which can be lowered when required between the needles *l* and the cards upon the cylinder *r*, it being of such dimensions that when thus interposed and subjected to the action of the cylinder-batten, it pushes in the whole of the set of needles it covers, thus neutralizing the action of the cards, and throwing the hooks out of contact with the griffe, as long as may be required. This interposition is easily brought about when the weaving of the fabric has progressed to the point where the formation of the central design has to commence. Thus blocked, the mails would remain inoperative, and the warp threads would not be woven into the fabric, were it not for their connection by the lines of the second set of harness with the supplementary jacquard *b*. As soon, therefore, as the central figure has to commence, the weaver stops his loom, interposes the block-plate *o*, on the first jacquard, throwing the set of needles *l* out of operation, and brings the apparatus *b* into gear by moving a sliding clutch which engages it with the boss of a lever from which it receives motion. This brings into action the second set of cards which are perforated to produce the central figure instead of the general ground. When the design is completed, the second apparatus is thrown out of gear, the block-plate *o* is drawn up, and the set of needles *l* are permitted to resume their action. These changes are effected in a moment or two with perfect ease by any weaver, whether male or female.

1473.

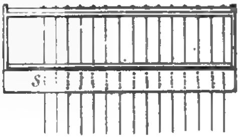


1476.





1474.



1475.

The inventor provides for the needles *l* being put out of gear in a variety of ways, as well as the above. The invention is also applicable to the production of more than one design upon one set of cards, and, in fact, in most cases where the design cannot be produced by one set. Any required number, or the whole of the mails may be connected with the second cylinder, and they may also be connected with the needles, either the whole or any number thereof, on what is known as the "five-end system"; or two or any number of needles may be connected with one needle. The above arrangement is all on the single-end system.

The manner in which the inventor prefers to produce the end or cross border is illustrated by Figs. 1474, 1475, 1476. Fig. 1474 represents a card-cylinder, and Fig. 1475 shows the arrangement of the needles to suit the cylinder. The vertical rows of needles *s* are spaced at twice the distance apart as compared with the rows of holes *t* in the cylinder, and there may be twice as many holes in each face of the cylinder as there are needles. In Fig. 1474, a portion of a card is shown in position upon the cylinder on the part marked *u*. The card is punctured with two sets of holes, the rows of one set alternating with the rows of the other, one set being shown by crosses and the other by dots. One of these sets of holes would produce the plain ground, or ground-pattern, and the other the cross or end border, referred to before. When the changes are required to be made, the cylinder can be moved laterally, in the direction of its axis, by suitable appliances; one means of doing this is shown in Fig. 1476, where it is seen that a gudgeon of the cylinder is provided with a collar, working in a slot in the link of an excentric *v*, which can be rotated to a sufficient extent in either direction by means of the cross lever *w*, whereon cords are attached for the purpose of bringing it within easy reach of the weaver. By pulling one cord, the cylinder moves in one direction; whilst by means of the other, it is brought back. A lateral movement of the cylinder to the extent of half the distance between the vertical rows of needles puts one pattern out and the other into action. In this manner, if desirable, more than two sets of patterns may be produced from one set of cards: thus one set of holes may produce the end borders; a second, the side borders and ground; and a third, the side borders, ground, and central design, thus dispensing altogether with the supplementary jacquard and its furnishings. From various causes, such as the failure of the automatic stop-motion to arrest the movement of the loom when the weft thread has broken, or from the necessity through the occurrence of a fault to unweave a portion of the cloth, the card gets out of proper relationship with the parts of the pattern last woven, in which case it is necessary to reverse its movement with facility and ease. Fig. 1476 shows a means whereby this may be readily done. There are two levers *x y*, the first being a presser-lever, and the second a catch. Both are furnished with cords at their free ends, by pulling which they can be lifted clear of the cylinder, which can then be turned in either direction with ease and rapidity by means of the endless band *z*, passing over the grooved pulley on the axis of the cylinder.

The economy effected by the invention will be easily seen from the following statement, which may be regarded as a fair average result of its application. Suppose a loom is required to be mounted for the production of a towel 40 in. long, and 90 picks to the inch. This, under the old system, would require 3690 cards, 600 long, the centre and border patterns being stamped on one card. If these patterns were on separate cards, as on a still older plan, 7830 cards would be required 300 long. By the improvement under notice, 600 cards 600 long will produce all the design. The expenditure on the first-mentioned system, requiring 3690 cards, would be as follows:—Cards, 5*l.* 18*s.*; punching the patterns, 5*l.* 5*s.*; band, 11*s.* 6*d.*; wire and wiring, 18*s.* 6*d.*; lacing, 1*l.* 7*s.* = 14*l.* The improved form would be: for cards, 12*s.* 8*d.*; punching, 18*s.* 8*d.*; band, 2*s.* 2*d.*; wire and wiring, 3*s.*; lacing, 4*s.* 6*d.* = 2*l.* 1*s.* In an economical point of view, this is of considerable importance in an establishment having a considerable number of looms.

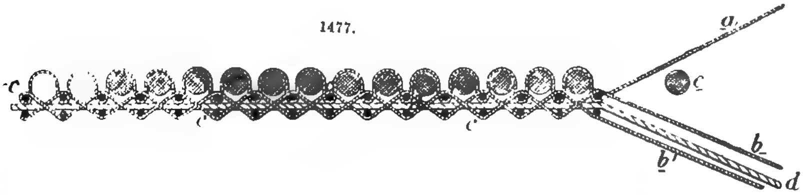
This heavy expenditure on the old plan has, however, led to the extensive adoption of the alternative method of changing the cards detailed above. But owing to the cost and the loss of time during working hours, it is questionable whether it is really of any considerable advantage. Also it may be remarked that any change in the length of the towel necessitates a corresponding change in the number of cards, which is a source of delay. The 600 cards on the improved plan weave any length required, and the change from the body to the border pattern is effected without stopping the loom. In fabrics having a medallion centre, on the plan generally in use, 1800 cards are required for border and filling in addition to the ordinary set, and these need to be changed six times during the weaving of each cloth. This improvement requires only an addition to the ordinary set of the actual cards used in weaving the centre figure, whilst changing is altogether dispensed with. Its advantages will therefore be fully obvious.

In carpets such as Brussels, tapestry, and pile fabrics generally, the body, backing, or foundation forms the true fabric, with which the pile-threads are interwoven. The latter are usually of a different material, and are interwoven in such a manner as to form a terry, looped, or pile surface. The weaving of these articles differs only little from that of plain fabrics or those woven by the jacquard. All that is required in addition is mechanism by which the pile-threads can be formed into loops on the surface during the process of weaving. There are several plans of doing this, but the one in highest favour is that wherein wires are introduced into the "shed" or opening formed between the body and the pile-warp, and which, when the threads of the latter have been woven down into the body-fabric, are withdrawn, leaving a line of loops across the width of the fabric. Previously to 1850, nearly all carpets of these kinds were woven by or on hand-looms. This was a laborious occupation, and the production of each weaver was a small length per week. There have been considerable improvements since the date mentioned, by which the quality has been improved and the production increased. There are yet in use in both this country and America a considerable number of hand-looms, chiefly employed with jacquard attachments on the production of ingrain and damask carpets.

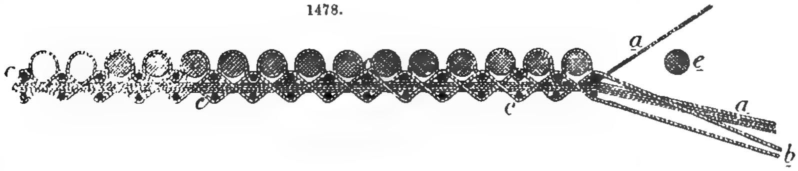
Mechanicians in the field of carpet manufacture had a comparatively easy task before them. The power-loom with the jacquard attachment was ready to their hand in a very perfect condition. All it required was that its different parts should be strengthened and adapted to withstand the shock of driving home the filling in a heavy fabric like a carpet. This was easily accomplished, as was the addition of a strong pacing or warp-delivery arrangement and taking-up motion. The principal part requiring to be invented, and which is peculiarly an adjunct of the pile-fabric loom, was an automatic method of inserting and withdrawing the wires by which the loops of the pile are formed. Another important point was to combine this apparatus with the mechanism of the power-loom as employed for weaving either plain fabrics or those with jacquard patterns. After some difficulty, this was successfully accomplished, and since that time the carpet industry has rapidly extended in this country, and of late years also in America.

Figs. 1477, 1478, 1479 illustrate the construction of the fabrics known as tapestry, Brussels, and velvet-pile carpets. The first is a longitudinal section of the tapestry carpet, with the shed open for the insertion of a looping wire. It will be observed that the warp consists of three distinct portions. The pile-warp *a* is usually composed of printed worsted yarns, the design being printed in such a manner that when woven and piled in the fabric, a pattern shall be the result. The next is the body-warp *b b′*, usually of linen or cotton yarns; of late years, the latter have come to be preferred, as it is found from their greater pliability that they wear better than linen warps for backs. This warp binds the whole fabric together, being interwoven with the weft, the threads of which are seen in section at *c*, forming two series, one under and one over the third warp *d*. This warp is introduced to give thickness or substance to the fabric, and in tapestry is generally composed of some softly-spun, cheap material which will allow the other portions to embed themselves in it,

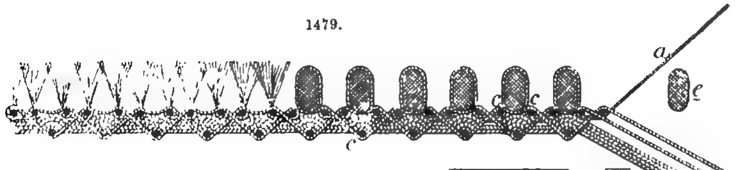
1477.



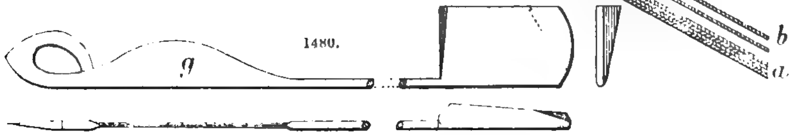
1478.



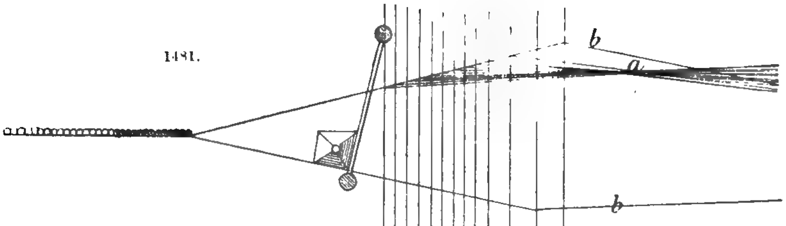
1479.



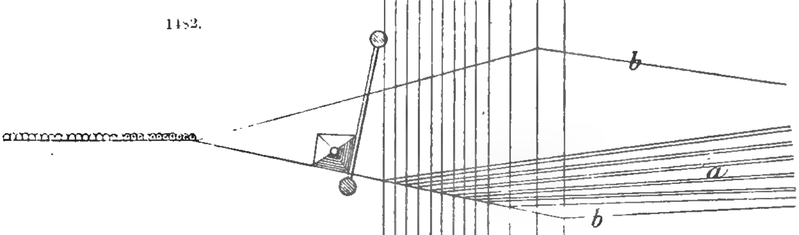
1480.



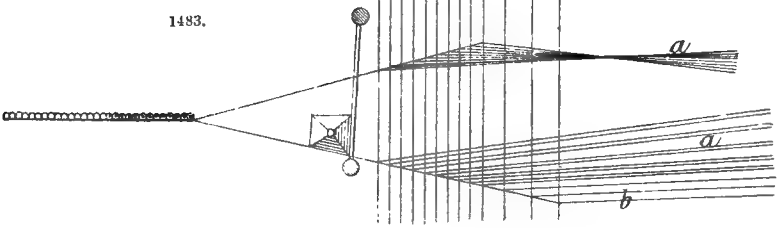
1481.



1482.



1483.



so that during wear the pile-threads will not easily allow themselves to be drawn from their position. The threads of this warp neither rise to the front nor descend to the back of the fabric; being introduced only for the purpose before named, they are retained in the centre of the fabric. The threads of the pile-warp *a* are never taken below the filling-warp *d*, consequently they never appear at the back of the fabric, which fact explains the absence of coloured threads at the back of a tapestry carpet, by which inexpert people are best enabled to recognize its true texture. In weaving, the whole of the pile-threads are lifted and lowered at once; when raised, it is for the purpose of admitting the introduction of a new wire as seen at *e*. When lowered, one portion of the body-warp *b* is raised to form a shed for the weft, which has the filling-warp *d* raised to form a different shed for its return. The course of each warp and its function in the construction of the web can easily be traced from the diagram. After a sufficient length of the fabric has been woven to prevent the tension on the pile-warp drawing down the loops, the wires are withdrawn, and are then ready for renewed use.

Fig. 1478 represents a similar section of Brussels carpet with the shed in like manner open for the insertion of a new wire. The texture of the fabric is very similar to the preceding, so far as the interweaving of the threads goes. The body-warp *b* serves the same purpose as in the preceding case, but is differently composed, there being three, four, or five times as many threads in the pile-warp as before, and only $\frac{1}{4}$ or $\frac{1}{5}$ of these are raised at one time to form the pile. The remainder take the position of the filling-warp in the tapestry carpet. In Brussels carpet, the pile-threads are individually of one colour only, and not printed to form the design as in tapestry, the jacquard lifting the coloured threads to form loops as required by the nature of the design. Some of the pile-threads being required to be raised very frequently, and others only at long intervals, necessitates the use of a creel or bank in which bobbins containing only one thread each are placed, in this differing from the tapestry carpet. The pile-threads are all wound upon one beam. The embodiment of such a large proportion of the pile-threads in the filling-warp causes the colour of the threads to appear at the back—indubitable evidence of its being a true Brussels texture.

Fig. 1479 illustrates the construction of the web of a velvet or cut-pile carpet, which is almost identical with the Brussels in texture, except that two threads of weft *c* are used for binding the pile. The pile wires *e* are also elliptical in the form of their section, thus making a deeper pile when inserted; and, being furnished with a knife-edge at the distant extremity, cut the loops when withdrawn, as illustrated in Fig. 1479. Fig. 1480 is a full-size illustration of the wire used for weaving a cut-pile fabric, *g* being the blade or cutting end.

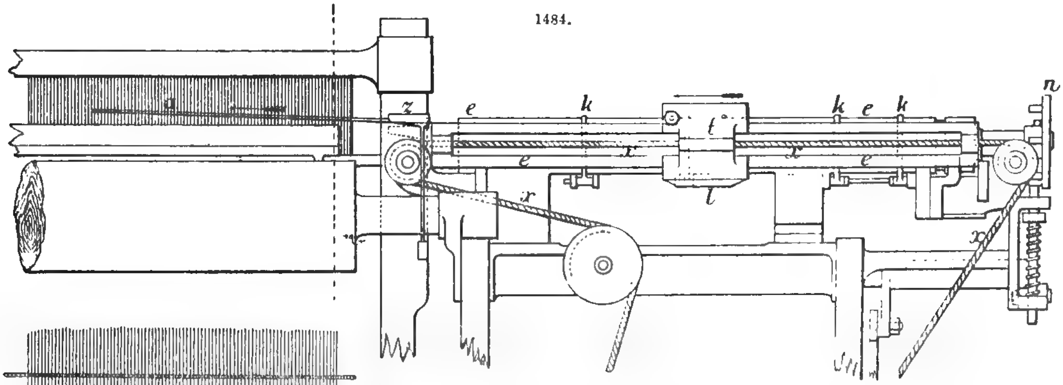
Figs. 1481, 1482, 1483 exhibit the order of "shedding," by which the Brussels carpet is composed. Fig. 1481 is for the passage of the shuttle and the reception of the weft. All the pile-threads *a* have been raised, and also one-half of the body-warp *b*, the remainder being left down. The shuttle is then thrown through the open shed, leaving the pick of weft that shows itself at the back of the fabric. The next movement opens the shed shown in Fig. 1482, which is also for the passage of the shuttle, and the reception of a thread of weft. In this, all the pile-threads are down, and the two portions of the body-warp *b* remain as before, the shuttle traversing the shed again puts in the top pick or thread of weft, which is the binding pick by which the loops formed upon the wire last inserted are tied securely in position. Fig. 1483 shows the last shed necessary for the formation of this particular fabric. It is for the reception of the wire used in the formation of the loops; all the body-warp threads *b* are left down, also all the pile-threads *a* not required for the design; those needed to form the pattern are lifted by the jacquard, and, on the insertion of the wire, are retained in loops by it until a binding thread of weft has tied them down. To keep them securely fixed, the wires are left in until a sufficient length has been woven to prevent them being drawn backwards.

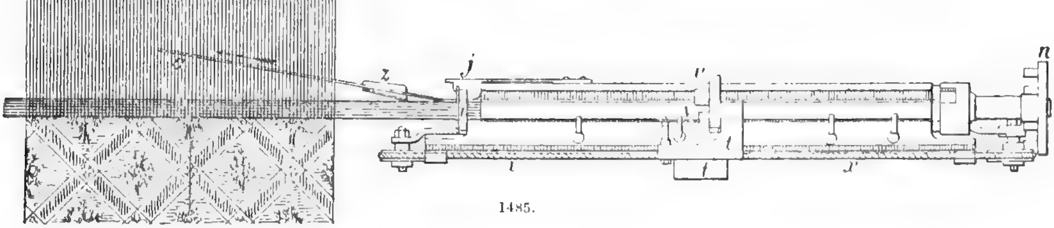
As observed before, the problem to be solved in connection with the carpet-loom was the invention of an automatic plan of inserting and withdrawing the wires to form the loops. As in connection with nearly all other mechanical inventions, the present approximately perfect system has been the result of growth, the first rude effort serving as the foundation upon which succeeding inventors have built. An arrangement was first constructed by which from a bundle of wires a single one was successively drawn as required, and, by means of a pair of nippers, fixed at the end of a reciprocating rod, was carried into the shed; and after having been woven into the fabric and subsequently withdrawn from the loops, the wires were returned by the hand of the weaver to the bundle. An improvement followed this by which the whole operation was rendered self-acting. This consisted of dropping wires successively from a hopper into a longitudinal groove in a rod, which was carried into the shed in guides, and was then caused to make a half-revolution by means of a screw-incline on the rod, by which the wire was dropped into its place in the shed. The wires were successively withdrawn from the fabric by reciprocating nippers, and carried up again into the hopper by endless chains. The next step was to simplify this by a plan of placing the wires separately in a groove from which in succession they were pushed into the shed, and being constructed with a hook at the back end, each was subsequently, at the proper moment, withdrawn and transferred to the feeding-trough for use again.

In these first attempts, various means were used to support the forward extremity of the wires, as it was assumed that they could not be otherwise held with sufficient rigidity to secure their correct insertion without being thus sustained. This plan was, however, afterwards abandoned, as by the aid of further improvements it was shown to be unnecessary.

Some years ago, W. Weild, of Manchester, invented a system of inserting the wires in carpet-looms which, with subsequent improvements, has remained in favour up to the present time. This plan is known as the roller wire-motion, and is fixed to one side of the loom. Figs. 1484, 1485, 1486, show front elevation, plan, and section of this attachment. In the two first figures, a wire *a* is shown being inserted into the shed of the fabric. In the plan, Fig. 1485, is shown a portion of the woven fabric, and the reed with which the weft and the wires are pressed to the fell of the fabric—the part last woven. Fig. 1486 is a transverse section of the roller *r* in its casing *e* and the slide *t* for inserting and withdrawing the wires. The roller and its casing *e* are rather longer than the width of the carpet to be woven, and the upper part of the casing is cut away through the extent of one-sixth of the circumference of the roller, as shown in the figure. In the surface of the roller *r* six longitudinal grooves are cut, of a width and depth corresponding to the diameter of the wires. The roller enclosed in its case is fixed with its end about 9 in. from the edge of the carpet, and with its upper surface parallel and in the same plane as the "fell" of the carpet. At the end of the casing nearest the warp, a recess is formed between the end of the roller *r* and a hoop *i*, Fig. 1485, concentric with the roller. In this recess, which extends through $\frac{1}{6}$ of the circumference of the roller, the heads of the wires are held when inserted in the fabric as shown in the plan. The hoop keeps the heads of the wires down in their places, and prevents them being pushed too far into the warp, and at the same time prevents their being withdrawn before the proper moment. A projection upon the end of a spring *j* attached to the side of the casing keeps the heads of the wires erect, pressing them against each other, and against the end of the recess during the whole time that the wires remain inserted in the carpet. At the opposite end of the roller, is a projecting collar formed all round the roller, between one end of the casing *e* and a hoop carried by a bracket. This collar contains six grooves in which to receive the heads of the wires, and retain them in their correct radial position, whilst being carried round by the roller, in the direction shown by the arrow in the sectional view. When the roller is stationary, two of its six grooves are opposite the two extreme wires in the recess *i*, Fig. 1485, one being opposite the wire last inserted, and the other opposite the wire next to be withdrawn from the fabric. The other four grooves *h* have each a wire lying in them as shown in the section, so that each time the roller makes $\frac{1}{6}$ rev., one wire is brought round to the place for insertion into the shed of the warp, and the wire last drawn from the carpet is carried away.

1484.

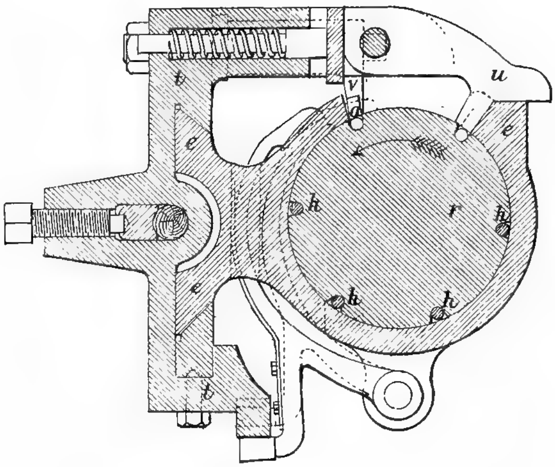




1485.

On the front of the casing *e*, a slideway is formed parallel to the axis of the roller *r*, upon which is fitted a slide *t* carrying a finger *u* for inserting the new wire, and the pawl *v* for withdrawing the last wire. The finger is hinged upon the slide *t* by a spring-joint, as shown in the section, so as to be steadily held when either up or down. When down, as in Fig. 1484, it slides against the inserting edge of the casing *e*; and a recess in the extremity of the finger fits over the head of the wire that is being inserted, so that, as the slide *t* traverses inwards towards the carpet, the finger *u* pushes the wire forwards into the shed, holding it down into the groove of the roller. When the slide arrives at the inner end of its traverse nearest to the carpet, the pawl *v* is tripped up by the head of the wire next to be withdrawn, and drops on the inner side of the head, and the wire is then withdrawn by the pawl during the outward traverse of the slide *t*. In order to prevent the wire, whilst being withdrawn, escaping from the groove in the roller, several curved fingers *k* are used, jointed to the under side of the casing. The ends of these fingers cover the groove which receives the wire withdrawn, as shown by the dotted lines in the section, and each finger is pressed down upon the roller by a spring acting against the side of the hole through which the finger passes in the casing *e*. These fingers have to be lifted out of the way successively, in order to allow the head of the wire to pass; and this is done by a double incline *l* upon the bottom of the slide *t*, which acts upon the projecting tail of each finger in succession during the traverse of the slide.

1486.



The slide receives its traversing motion from a rope *x*, which is secured in a hole in the slide by a block and set-screws, Fig. 1484; this rope passes over guide-pulleys at the ends of the roller-casing *e*, and then downwards to a larger pulley not shown in the drawings, to which the two ends of the rope are secured. The shaft of this pulley carries a pinion-gearing with a toothed sector, which is centred at the top in the framing of the loom, and is worked backwards and forwards by a drum-cam upon a shaft behind. This cam is shaped to produce a quick forward traverse of the slide *t*, so as to insert the wire quickly whilst the shed is held open for it; but it gives a slower backward traverse to the slide, so as to withdraw the wire slowly, having more time in which to perform this operation, as a wire is inserted only in every third shed.

After each wire has been inserted, the wire roller *r* is turned round through $\frac{1}{6}$ rev. in the direction of the arrow, by means of appropriate mechanism. A cam upon the end of the cam-shaft gives motion to a lever, oscillating upon a centre in the framing of the loom; and the other end of this lever has a forked pawl jointed to it, which is kept pressed by a spring against the pins in the disc *n*, secured upon the end of the wire roller. The wire is held steady by a T-piece sliding vertically, and which is pressed upwards by a spring against the pins in the disc *n*. The wires lying in the grooves of the roller, previous to insertion into the fabric, project 2–3 in. beyond the inner end of the roller; and if the point of the wire went straight forwards as pushed from the roller groove, it would be impossible to make it enter the shed correctly, as it would then be so close to the fell of the fabric, or junction of the warp threads forming the fell or angle of the shed, that the point of the wire would inevitably catch these threads. The wire is consequently sprung or deflected upwards, as shown at *a*, Fig. 1485, by means of the short grooved guide *z*, through which the wire passes as it is pushed out of the roller groove. This guide is fixed upon the top of a vertical rod which is moved up and down by a lever actuated by a cam, and when the wire has been pushed nearly through the shed, the guide is lowered into the position shown by the dotted lines in Fig. 1484, to be out of the way of the wire at the moment of its being driven up by the reed, after which it is lifted again to be ready for the insertion of the next wire. The springing of the wires by the guide in directing them into the shed might at first sight appear objectionable, but the amount of this bending does not exceed what they will recover by their own elasticity, and the experience of working during several years has proved it to be of great advantage, because the bending stiffens the wire and makes its point steadier whilst passing through the shed. Besides this, in consequence of the angle at which the guide causes the wire to enter the shed, the point of the wire comes into a wider part of the shed, the further it passes through the shed; and thus as the unsteadiness of the point of the wire increases with the greater length unsupported in the shed, more space is allowed for its vibration without risk of its catching the threads forming the shed.

Owing to the position of the roller wire-motion at one side of the loom, the shuttle-box on that side has to be made detached from the ordinary sley or batten. It is therefore carried upon separate sley-swords, which oscillate upon a shaft coinciding with the shaft of the ordinary sley. This loose shuttle-box is actuated by a cam upon the crank-shaft of the loom, which acts upon a roller in a rod jointed at one end to the shuttle-box, the other end of the rod being slotted to slide upon the crank-shaft as a guide. The cam is shaped so as to actuate the loose shuttle-box in such a manner that it will come opposite to the sley and have a motion identical with it at the time the shuttle is passing into the shed. The description of this ingenious attachment to the carpet-loom is substantially that of the inventor. On good looms, to which it has been added, a production of 42 yd. a day as an average is easily attainable, including stoppages.

During the past few years, several important improvements in the carpet-loom have been introduced, the object of which has chiefly been to simplify the mechanism and facilitate production. The Bigelow loom, the first successful power-loom for the manufacture of carpets, was an American invention, and we are indebted to that country also for several recent improvements of an important nature.

The standard make for Brussels carpet is 8 wires for 1 in. of length and 27 in. of width of carpet. The difference in the work involved and in the quality consists in the greater or less number of coloured threads used in the pile-warp for forming the pattern; in the best carpets, these amount to 1300, all of which are to be brought up to the surface in turn and kept in order. About $\frac{1}{5}$ of these must be lifted by the jacquard at each insertion of a wire, to ensure its being completely covered all across the fabric. To the above threads have to be added those of the body-warp, about 400 in number, thus bringing up the total in a good Brussels to about 1700, each of which must have a separate mail or cord, so as to permit of its being picked up individually whenever required by the design.

In the manufacture of carpets, as in other goods, great changes have been produced by the extension of our commerce. English wools, such as britch, saycast, matching, neat, brown drawing, and other sorts were formerly the main bulk of those consumed. These, however, would now be too expensive, and consequently have been superseded by foreign wools, such as E. Indian, Persian, and other barbarian wools, i. e. wools from unimproved breeds of sheep, many of which possess very good qualities for carpet purposes. Oporto wool is in high estimation, yielding a soft, lustrous yarn, which covers the grounds very well, and is extensively used for medium shades of colour, and for browns, yellows, &c. Best whites are made from high class English wool, whilst low whites are obtained from an inferior quality of our home produce. The former are also used for white shades and light drabs; a medium quality is used for general purposes, and is suitable for such colours as reds, browns, and most dark shades. For black grounds, it is most economical, and also satisfactory as regards quality, to use a level, full, and well-spun grey yarn. Less dyestuff is needed to get the required shade, which, when it is obtained, is as solid and durable as that upon a white yarn, though the dyeing will have cost 20 per cent. less.

The quality of carpet pile-yarns is judged high when it is free from lumps and kemps, and is evenly spun in every respect. It is far the wisest course, though not quite a common practice, to scour samples of all yarns intended to be bought, because this reveals the faults, especially when unevenly spun or twisted, which causes it to "cockle" or twist up, arising from the strands having shrunk unequally; this fault gives much trouble in after processes. When the sample hank has been scoured, it should be compared with that in the grease by extending it upon the hand; if it has shrunk very much or has "cockled," it will not prove a satisfactory yarn in working, and ought to be avoided. It is also desirable to carefully ascertain the diminution of weight after scouring, because much loss may accrue from buying yarns heavily laden with grease. The strength of the yarn is always an important matter, and care should be taken to have it of a quality equal to the work expected from it. Both in this respect and in regard to fineness, it should be tested frequently; in the latter, in every delivery when the yarn is purchased from outside. When the test shows it to be within a quarter of a count of the nominal fineness, it is regarded as correct.

Scouring the yarns is simply the process of clearing them from the oil and grease of previous stages, and is ordinarily performed in a "wash," or bath of water in which soap or honey soda has been dissolved. Several special methods have been adopted for doing this efficiently, but these require no particular description, as the object of all is to clear the yarn perfectly. The system by which this result can be secured most completely is manifestly the best one, and any plan falling short of this is not to be adopted. Well-cleared yarns take the dyes more perfectly than others, and yield a better result.

For dyeing purposes, copper, wooden, or stone vats are usually employed. Of these, perhaps those of stone are most eligible, for they do not absorb and retain the colours to the detriment of succeeding baths, as do those of wood, and are rarely if ever affected by acids, as is sometimes the case when they are composed of metals.

Several hank-dyeing machines of considerable merit have of late years been introduced into the various textile industries wherein dyeing is a branch of the process, and these have found favour amongst carpet-manufacturers, because of the greater uniformity of colouring obtained by their use. The hanks of yarn are by means of the machine simultaneously immersed in the dye-bath, and in like manner withdrawn when required, all being thus uniformly exposed. A recent improvement also enables the hanks to be automatically wrung, which ensures every hank being twisted exactly alike, whereby the liquid dye is equably expressed, and evenness of shade is secured.

By these various improvements, carpets are now produced, and enabled to be sold at very low prices, whilst retaining excellence of quality and beauty of design.

Besides the pile-warp, which is always composed of worsted, there are three other varieties of yarn that enter into the composition of a carpet: the "chain," the "shute," and the "stuffer." The former is amongst manufacturers preferred to be of linen, for the reason chiefly that it gives weight and firmness to the fabric in a superior degree to cotton, though the latter is a better wearing article when of good quality, and is often if not always more economical. When linen warps are used, the sizes are usually 5¼, 5½, or 6 lea good tow yarns, the middle number being the most common. In cotton, the numbers are usually 8's 9's and 10's 3-fold, the first prevailing as regards quantity consumed. Jute has been tried, but has not been found to be a satisfactory substitute. For the shute or weft of the fabric, linen is always used, as, not requiring to be so hard spun as the shorter fibre of cotton, it is more easily embedded in the warp threads, and covers them in a superior manner. The stuffer warp is composed of low cotton-waste yarns, called "bump" yarns, the single thread of which runs about 70 yd. to 1 oz. Its purpose is to stuff or fill tapestry carpets, hence its name. This class of yarn is the best known article for the purpose. It is produced principally in the neighbourhood of Oldham. The chief requisite of quality is evenness.

Chain, shute, and stuffer yarns are all sized before being used. The "sizes" employed are composed of different materials, such as horn piths, old pickers, glue, and one which is glue in an unfinished state. These are preferred by individual manufacturers for different reasons, some of which can hardly be distinguished from sentiment or prejudice.

Designs.—The most important part of carpet manufacturing is to secure good designs. In 9 cases out of 10, if not in 99 out of 100, a carpet is sold by the design, the intrinsic quality being taken into consideration only as a secondary matter. Of course, the best designs are always utilized for the highest qualities, because they are most likely to be selected by consumers possessing taste and culture, which qualities are usually found associated with fair means or social position. Large establishments possess designing departments under the superintendence of first-class men. Smaller establishments procure their patterns from professional designers, who make designing a separate business and sell their productions to all comers. Schools of art have done much to improve taste and increase competition in this branch, and it is not difficult to obtain excellent designs in this manner.

Another important requisite of this branch of the art is that of being a good colourist. A capital design may easily be spoiled by incongruous or inharmonious colouring. When a good design, however, is secured, it is desirable to make the most of it, which can often only be done by bringing it out in from three to ten or twelve colourings, in order that it may harmonize readily with a great variety of surroundings. It is frequently discovered also that the designer's arrangement of colour can by a slight modification be improved upon, and this is sure to show itself under this varied treatment. To most establishments is attached a man whose duty is to try the effect of slight alterations in the colourings, and improve them where possible. An indifferent design when skilfully coloured is often more successful in striking the public taste than a better one where the colouring is not so well done.

Products.—Having brought under notice a condensed view of wool as a raw material, showing its nature, variety, sources of production, and chief applications, and having followed it through the various processes of the three principal industries of which it forms the basis, and in which it is transformed into articles of utility, a brief enumeration of the varied products may be permitted.

Woollen goods is a comprehensive phrase, and includes all those articles manufactured from carded wools by the processes previously described. At the head of this class, deservedly stand the celebrated broad-cloths of the West of England. In the last century and during the first half of the present one, scarcely any articles except broad-cloths, plain woven fabrics, and Kerseymeres or twilled fabrics, were available for the consumption of the male sex. These were uniform in colour, variety of colour and shade being all the changes available to meet the demands of fashion. The first-mentioned article has undergone no important change for centuries, except approaching greater perfection of finish, arising from improved methods of manufacture and the introduction of finer wools. The industry is widely spread, but in no centre are the articles produced by the West of England surpassed in the best and most essential qualities of a good fabric,—thickness, solidity, suppleness, fineness, and beauty. This has been amply demonstrated at the numerous international exhibitions that have been held during the past 20–30 years, and which have permitted comparison to be made with the productions of other nations. In the best goods, the highest priced Silesian or Electoral wools are almost exclusively employed. A lighter class of these fabrics are made in Germany, the beauty and excellence of which can hardly be surpassed. Those of France also possess high qualities. America scarcely produces any broad-cloths.

A great change was inaugurated in the manufacture of cloths in 1834 by the adaptation of the jacquard attachment to the production of fancy woollen cloths. This was first done by Bonjean, a woollen manufacturer of Sedan. He conceived the idea of modifying the plain cloths hitherto universally made, by uniting upon the same stuff different tints or patterns of tissue, which he was enabled to effect by means of the jacquard. It was soon evident that there could be no end to the variety of patterns that could now easily be produced, and that fancy could henceforth be allowed free play. From this fact, the name of "fancy" woollens was derived. This process was soon extensively imitated in France, Germany, England, and America. In the last country, George Crompton, a Lancashire emigrant, having his attention drawn to these goods, invented a loom specially adapted to their production, and which, known by his name, has since been extensively introduced into the trade. Similar looms have been devised by other inventors, and a large trade in these goods has been created in all countries possessing an established woollen industry. As a consequence the products are innumerable, and in style and pattern vary with the changing seasons.

Flannel manufacture is a considerable branch of the woollen trade. Flannel is cloth which only passes through two or three of the processes subsequent to weaving. Flannels are extensively worn by all classes of society, both male and female, for under-garments, for which they are exceedingly well suited. They are extensively produced in England, Germany, France, and America. A comparison of English and American flannels shows that the latter have the yarns rather more closely twisted or spun, to prevent or diminish shrinkage. Flannels are made plain, twilled, dyed and printed, and in unions of cotton warp and woollen filling, or otherwise, as more frequently of late, the cotton being introduced in the fibrous state, and mixed with the wool in the earliest stages. A high class article is obtained by the employment of a silk warp, and yarns from a high grade of wool. Blankets for bed-wear are a heavier description of flannel, and constitute an extensive manufacture.

Worsteds, the next great class of textures of which wool forms the raw material, offer much greater diversity than the preceding. The first point of difference is that the yarns are composed of combed wools, and the fabrics are rarely shrunk in any stage of the manufacturing process. Thirty or forty years ago these products almost exclusively appertained to female uses, as did woollens to men's purposes. Since that time, however, great changes have taken place, and the softer sex have successfully claimed a large portion of the products of the woollen industry, whilst on the other hand men have occasionally adopted worsted goods for wear, especially in coatings. As a division, this branch is equal to if not superior in importance to the woollen manufacture.

The fabrics produced in worsteds are almost infinitely varied. The names, however, by which they are distinguished are purely fanciful in most cases, and afford no clue either to the class of the material of which they are composed, or the method of fabrication. These names are usually given by the manufacturer or merchant who first introduc s them, and if they should prove successful, it is not often long before the name is attached to some other fabric of quite another character, or at least a degraded imitation. To suit the public craving for variety, old fabrics are continually reappearing under new names; and with some slight modification still more frequently. Hence the great confusion which exists amongst distributors and the public, who are bewildered thereby, owing to the want of some rational or scientific system of classification.

The texture, "weave," or *armure* as the French call it, offers the best basis for a classification of woven goods, and might, paying due regard to the other elements of the fabric, form also the basis of a system of scientific nomenclature, though it is doubtful whether such could ever become a substitute for that popularly current. The texture or weave means the order of the interlacement of the warp threads; the French designation *armure* means the system of harness with which the loom is furnished or armed. There are four of these systems which may be regarded as fundamental, and which are employed to produce nearly all the varieties of simple fabrics. In the first or "taffeta" weave, there are only two harnesses, forming a simple interlacement of the threads, such as used in the production of plain broad-cloth, calico, or *mousselines-de-laine*. In this, alternate threads of the warp rise together, the intermediate ones being depressed to form the shed for the passage of the shuttle and the introduction of the weft. When a thread of the latter has been put in, the elevated threads descend, the bottom ones rise, and another transverse or weft thread is inserted, the previous one having been driven home by the sley. The next is the "twilled" or

"Batavia" weave, in which four harnesses are employed, and in which the four leaves of the harness ascend in successive order, producing a pattern upon both sides of the fabric, which takes the form of a diagonal line across the width, the pattern on the back running in an opposite direction to that on the front. The third is the "serge," a 3-harness twill, the effect being a similar pattern to the above, but upon one side only, the back being in this case plain. The fourth is the "satin" weave, and is produced by five or more harnesses; the effect in this is to bring the weft threads most conspicuously to the surface. Many of these are often combined with one another, or with "fancy" weaves, one of which is the leno, in which the warp threads are made to half twist round each other, and are fixed in that position by the weft. By these means, and the combination of various materials or colours, numerous and widely different effects are produced.

The following table of worsted stuffs composed of the finer classes of combing wool will prove instructive, and illustrate the foregoing observations. As will be seen from the names, the first portion of the list is chiefly French, and is from Alcan. The later is English. Both are, however, common in many cases to England, France, and America.

Name of Fabric.	Weave.	Warp.	Weft.	Remarks.
Manteau	Taffeta	Carded wool	Carded wool	.. ..
Reps	„	Wool	Fine wool	Made of long combing wool, and wide for furniture.
Turquoise	Serge	„	Wool	Woven in checks and Scotch plaids, the warp having a serge *armure* of 2 and 1, and the weft a serge *armure* of 1 and 2.
Merinos	Batavia or double twill.	Fine wool	„	Made of 8–50 picks per *centim.*; formerly very popular, but latterly quite gone out of favour.
Cashmere	Single or one side twill. Serge.	„	„	Made like the above in quality. A fabric yet in considerable favour.
Drap d'été	„ „	„	„	The warp double.
Mousselines-de-laine	Taffeta	„	„	.. ..
Moulletons	Satin	Wool	„	.. ..
Poplin	.. ..	Silk or wool	English wool	Poplins are either silk and wool, all wool, silk schappe and wool, cotton and wool, or fancy printed. The poplin or corded effect is produced by the thickness of the weft threads.
Barége	Gauze or open taffeta.	Cotton	„ „	Generally a printed fabric.
Challis	„ „	Silk grége	Merino wool	Differs from barége only in the materials.
Grenadine	„ „	Silk grége, organzine, or cotton.	English combing wool.	The weft is much twisted and gased; a kind of close barége.
Llanos	„ „	Cotton	Mohair, or mixed with silk.	The warp composed of 3 threads, white; while the weft is violet, blue, or black, which give reflections to the stuff.
Toile de Saxe	Taffeta	Cotton, single or twofold.	English wool	Peculiar finish.
Cretonne	„	Cotton, double and twisted.	Wool	Has a peculiar elasticity, due to the hard spun warp.
Jupons	„	Single cotton	Carded wool	.. ..
Vode	„	Wool	.. ..	For réligienses.
Valencias	„	Silk schappe	Combed wool	.. ..
Damask	Figured or fancy	Wool or silk	Wool	Furniture uses.
Bolivar	Taffeta	Wool	„	A light flannel made in grey, or in all varieties of colours.
The following are chiefly English,—				
Delaines	Taffeta	Cotton	Medium wool	Printed.
Baréges	Gauze	„	„	An open weave.
Reps	Double threaded taffeta.	„	„	Printed.
Cashmeres or Coburgs	Twilled	„	Merino wool	Made in imitation of Cashmeres d'Écosse, all wool.
Alpaca, formerly Orleans.	Taffeta	„	Long lustre wool	Weft originally of alpaca.
Brilliantine	„	„	Fine mohair	Usually black; the warps dyed before weaving.
Lustres	„	„	Lustre wool	An alpaca of lower grade.
Fancy alpaca	Figured fancy weave.	„	„	.. ..
Brocade	Taffeta	„	„	A corded ground with a figure.
Poplin	„	„	Long combing wool	Corded effect produced by thick weft.
Debaige	„	„	Weft made from black and white wool mixed.	.. ..

This list, were it required, could be greatly extended, but the examples given will suffice. During the past few years, worsted fabrics have been quite out of vogue as dress materials, the demands of fashion requiring softer fabrics than can be produced from the long English wools. The worsted industry has therefore suffered from considerable depression, and this has seriously depreciated the price of English wools. The trade is now in a transition state, a considerable number of the largest capitalists therein being engaged in altering their machinery to manufacture fine short wools consumed in the production of soft all-wool goods.

Besides Kidderminster, Brussels, and tapestry carpets, sufficiently described already, there are several other varieties which call for brief notice. Persia may be regarded as the birthplace of the carpet manufacture, and its productions have formed models for the imitation of all countries. Persian carpets or rugs are chiefly made in Kurdistan, Khorassan, Feraghan, and Kerman, each district producing a distinctive style and texture. The finest are those of Kurdistan. In these carpets, the most perfect taste is generally manifested, the pattern never representing flowers, bouquets, or other objects, thrown up in relief from a uniform ground, as in European and American styles, but wrought so as more to represent a layer of flowers strewn under the feet of the observer. They are furnished with borders always well accentuated and of brighter colours than the centre. Feraghan carpets are not unlike those of Kurdistan, but are less close and of simpler pattern. They are cheaper, and consequently in more general use. Khorassan carpets are superior in texture to the last, and usually more realistic in patterns. The carpets of Kerman are still more realistic in style than those of Khorassan, and in value approach those of Kurdistan. In form, Persian carpets are usually rather long and narrow, which renders their manufacture easier, and suits the shape of the rooms in which they are to be laid. Of all carpets, these are perhaps the most purely hand-fabricated, all being made without even the simplest machinery, the loom merely consisting of a frame on which the work is stretched. The woof consists of short threads interlaced with those of the warp by the fingers alone, and when a cross thread has been completed, a comb is inserted into the warp threads by which the weft is pressed or driven home. The pile is formed by merely clipping the protruding threads until an even surface is obtained. The weaver sits with the reverse side towards him, and depends upon his memory for the formation of the pattern. Persian carpets are admittedly superior to all other oriental products of the same class, being distinguished by their subdued tones and harmony of colours. Certain forms are repeated in all designs, which clearly mark their national character.

Turkish or Smyrna carpets, now extensively imported into the west of Europe, are in the best specimens generally designed with a flat border, or in other words without perspective, of flowers of the natural size, and with a centre of larger plant forms conventionalized, often to such an extent as to obscure the forms. The colours are negative shades of a medium or half tint, tending rather to dark, and possessing little of contrast, the result being a sombre effect. Many of those exported to Europe and America are of a degraded kind, being manufactured to meet the foreign demand.

Indian carpets are made in large single pieces adapted for covering broad floors. They usually possess a great variety of colour, but so evenly distributed, and each artistically balanced by its complementary and harmonizing hue, that the effect produced is exceedingly agreeable. The forms generally consist of highly conventionalized flowers and plants geometrically arranged.

The above classes fairly represent the productions of this description of article that have been the outcome of Asiatic phases of civilization, and afford a considerable contrast to those which may be deemed characteristic of the West.

The carpet industry in this country is widely distributed. Its chief seat, however, is the town and district of Kidderminster, which has numerous and extensive manufactories where tapestry, Brussels, Wiltons, Axminsters and other carpets and rugs are produced. Isolated establishments also exist in several of the southern counties, such as at Crayford in Kent, and Crewkerne in Dorset. In Lancashire, Rochdale is the chief if not the only place making carpets. In Yorkshire, it is an extensive industry, Heckmondwike, Halifax, Leeds and other places sending large supplies into the market. In the city of Durham, there is a considerable manufactory. In Scotland, the trade has been largely developed, Glasgow being a chief centre. Paisley, Glenpatric, Lasswade, Stirling, Kilmarnock, Perth, Forfar and Aberdeen all possess establishments engaged in this manufacture. Aberdeen is distinguished for its "Scotch" carpets of great excellence. Dundee has obtained a reputation for jute fabrics employed for the same purpose. In the various prisons of the country, mattings for floor coverings made from coco-nut fibre (see p. 939) are extensively manufactured, which serve the purpose of carpets in many humble households.

Statistics.—According to the Parliamentary return relating to the textile industries, and which has been quoted in previous articles, it will be found that in one form or another there are a large number of establishments engaged in the manufacture of wool. These are widely scattered over the different parts of the Kingdom, though of course chiefly collected in several great centres in England and Scotland. These mills differ considerably in magnitude: thus of the 420 woollen spinning mills in England and Wales exactly half are located in the Principality, which, for statistical purposes relating to these matters, also includes Monmouth. Against these, Yorkshire has 156, the remainder being scattered over the other parts of the Kingdom. But whilst Yorkshire employs in this department 7206 persons in its 156 mills, Wales in 210 mills only finds employment for 893 persons. It will properly be inferred from this fact that many of these only spin the local production of wool, and satisfy a very circumscribed demand for the product in their respective districts. The yarn from this source is chiefly woven on domestic looms, or consumed in knitting hosiery goods.

The following tables condensed from the report sufficiently exhibit the divisions and distribution of the trade throughout the Kingdom :—

	No. of Factories.	No. of Spinning Spindles.	No. of Doubling Spindles.	No. of Power Looms.	No. of Persons Employed.		
					Males.	Females.	Total.
WOOLLEN FACTORIES.							
England and Wales—							
Factories employed in spinning ..	420	501,952	38,822	..	6,422	4,316	10,738
" " weaving ..	65	..	..	2,917	1,715	2,188	3,903
" " spinning and weaving	786	2,236,429	212,377	47,332	41,728	48,239	89,967
" not included in above	141	..	..	..	3,298	1,796	5,094
Total	1,412	2,738,381	251,199	50,249	53,163	56,539	109,702
Scotland—							
Factories employed in spinning ..	85	238,480	15,612	..	1,802	1,233	3,035
" " weaving ..	31	..	..	2,098	920	2,415	3,335
" " spinning and weaving	116	320,541	46,401	4,186	7,091	8,705	15,796
" not included in above	14	..	..	..	270	231	501
Total	246	559,021	62,013	6,284	10,083	12,584	22,667
Ireland—							
Factories employed in spinning ..	42	10,359	732	.	250	131	381
" " spinning and weaving	25	29,846	4,210	411	697	775	1,472
" not included in above	7	..	..	..	87	35	122
Total	74	40,205	4,942	411	1,034	941	1,975
Grand total of woollen factories ..	1,732	3,337,607	318,154	56,944	64,280	70,064	134,344
SHODDY FACTORIES.							
England and Wales—							
Factories employed in spinning ..	11	11,859	3,906	..	189	128	317
" " weaving ..	4	..	..	199	105	165	270
" " spinning and weaving	37	71,843	5,376	1,911	988	1,108	2,096
" not included in above	82	..	..	..	876	1,504	2,380
Total	134	83,702	9,282	2,110	2,158	2,905	5,063
Scotland—							
Factories not spinning or weaving	3	..	..	..	5	11	16
Ireland—(nil).							
Grand total of shoddy factories ..	137	83,702	9,282	2,110	2,163	2,916	5,079
WORSTED FACTORIES.							
England and Wales—							
Factories employed in spinning ..	214	1,114,774	292,613	..	13,516	22,320	35,836
" " weaving ..	257	..	..	39,022	10,305	16,768	27,073
" " spinning and weaving	126	934,600	141,992	37,127	22,179	30,631	52,810
" not included in above	39	..	..	..	822	1,325	2,147
Total	636	2,049,374	434,605	76,149	46,822	71,044	117,866
Scotland—							
Factories employed in spinning ..	11	40,246	18,695	..	404	1,562	1,966
" " weaving ..	41	..	..	10,714	2,140	7,896	10,036
" " spinning and weaving	1	6,912	2,680	530	170	617	787
" not included in above	2	..	..	..	165	58	223
Total	55	47,158	21,375	11,244	2,879	10,133	13,012
Ireland—							
Factories employed in spinning ..	1	288	134	..	2	11	13
" neither weaving nor spinning	1	..	..	..	10	24	34
Total	2	288	134	..	12	35	47
Grand total of worsted factories ..	693	2,096,820	456,114	87,393	49,713	81,212	130,925

SUMMARY of the TEXTILE INDUSTRIES of the UNITED KINGDOM in which WOOL is the chief material employed.

Location.	No. of Factories.	No. of Spinning Spindles.	No. of Doubling Spindles.	No. of Power Looms.	Total Number of Persons Employed.		
					Males.	Females.	Total.
England and Wales—							
Woollen Factories	1,412	2,738,381	251,199	50,249	53,163	56,539	109,702
Shoddy „	134	83,702	9,282	2,110	2,158	2,905	5,063
Worsted „	636	2,049,374	434,605	76,149	46,822	71,044	117,866
	2,282	4,871,457	695,086	128,508	102,143	130,488	232,631
Scotland—							
Woollen Factories	246	559,021	62,013	6,284	10,083	12,584	22,067
Shoddy „	3	..	.	..	5	11	16
Worsted „	55	47,158	21,375	11,244	2,879	10,133	13,012
	304	606,179	83,388	17,528	12,967	22,728	35,095
Ireland—							
Woollen Factories	74	40,205	4,942	411	1,034	941	1,975
Shoddy „	Nil.	..	..	..	..	..	..
Worsted „	2	288	134	.	12	35	47
	76	40,493	5,076	411	1,046	976	2,022
Grand total	2,662	5,518,129	783,550	146,448	116,156	154,192	269,748

As the return, the figures of which are embodied in the above tables, was made to an address of the House of Commons of the 16th May, 1878, it follows that the information given therein was collected between that date and that when the report was presented to the House, namely 31st July of the year following. This it is well known was the severest period of the recent depression in commerce and industry from which the country is now happily emerging, and which consequently affected the returns to a corresponding extent. Also, as remarked in the return, some few manufacturers failed to supply the information required, though these were not many. Owing to improvement in trade and mill extensions since that date it will be a moderate estimate to say that the above figures will require an addition of fully 10 per cent. in every department to make them fairly represent the present (1882) productive capacity of the industry. The fact also should not be omitted to be made mention of that the return is only of establishments authorized to be inspected under the Factories and Workshops Acts, which take no cognizance of places where men only are employed, though these are few; nor of any portion of the domestic branches of these industries that yet survive in secluded localities. We have reason to believe that there is more of the latter than is suspected, but it is difficult to make an estimate. If, however, we permitted ourselves to do so, we should add about 2½ per cent. to the figures relating to the number of persons employed on the latter account. These would be found chiefly in Wales and Scotland.

Commerce.—Of wool and hair the chief raw materials consumed in the industries noticed in this article, in addition to the home product, the country requires a large supply from extraneous sources. The principal of these are Australia, New Zealand, the Cape of Good Hope, S. America, Russia, and smaller amounts from many other places. The Annual Abstract of the Board of Trade Returns for the year 1880 gives the following figures as those of our total imports of these articles for the under-mentioned years:—Of sheep and lambs' wool our imports were 460,960,907 lb., value 26,194,310*l.*, to which must be added for other kinds and flocks 2,135,772 lb., value 115,352*l.* Of goats' hair or wool, 13,566,019 lb., value 1,233,855*l.*; alpaca, vicuna, and llama, 2,548,056 lb., value 181,097*l.*; horse-hair, 27,471 cwt., value 181,215*l.*; cow, ox, bull, or elk, 85,122 cwt., value 103,482*l.*; unenumerated varieties, value 227,029*l.*; and woollen rags 41,266 tons, value 820,366*l.*, or a total value of 29,062,706*l.* Against these must be set exports of native grown and imported:—Sheep and lambs' wool (British), 17,197,300 lb., value 1,187,113*l.*; other sorts, including flocks and rag wool, 12,967,900 lb., value 546,671*l.*, or a total per contra of 1,733,784*l.*

Of manufactured and semi-manufactured articles from these industries we exported during 1880:—Of woollen (carded) yarn, 851,800 lb., value 106,922*l.*; of worsted (combed) yarn, the amount was much greater, 25,612,500 lb., value 3,237,818*l.* Of woollen manufactures:—broad-cloths, coatings, duffels, &c., plain, all wool, 10,406,400 yd., 11,430,400 lb., value 2,382,492*l.*; same articles of wool mixed with other materials, 26,509,100 yd., 28,988,300 lb., value 3,077,271*l.*; narrow cloths as in first item, all wool, 4,430,900 yd., 2,840,600 lb., value 537,933*l.*; same descriptions in mixtures, 8,653,800 yd., 5,775,800 lb., value 738,965*l.* Worsted stuffs, all wool, 17,192,900 yd., 7,083,200 lb., value 1,028,631*l.*; worsted stuffs, of wool mixed with other materials, 172,747,800 yd., 42,452,300 lb., value 6,212,525*l.* Blankets and blanketing, 6,388,700 yd., 7,453,000 lb., value 586,580*l.*; flannels, 6,697,800 yd., 2,400,300 lb., value 310,508*l.* Carpets, not being rugs, 9,328,300 yd., 14,593,900 lb., value 1,133,545*l.*; rugs, coverlets, or wrappers, No. 1,168,840, value 360,526*l.* The subsidiary branches yield the following:—Shawls, No. 736,892, value 157,803*l.*; hosiery, 320,026*l.*; small wares and manufactures of wool and worsted unenumerated, 418,312*l.*; yarn, alpaca, mohair, and other sorts unenumerated, 877,953. The total of these amounts is the grand sum of 21,487,810*l.* representing the value of our manufactured and semi-manufactured goods of which wool forms the principal ingredient.

The following figures afford a comparison of our imports of raw materials for several years past:—

Imports of Wool, &c., for	1876.	1877.	1878.	1879.	1880.	1881.
	£	£	£	£	£	£
Sheep and lambs'	23,244,554	24,203,137	22,786,563	23,282,753	26,194,310	25,825,821
Alpaca, vicuna, and llama	393,255	364,175	341,671	281,311	181,097	168,679
Goats' hair or wool . ..	729,535	983,366	752,909	743,615	1,233,855	748,083
Horsehair	202,472	157,600	131,356	114,964	181,215	—
Cow, ox, bull, or elk.. ..	175,023	263,418	62,870	55,199	103,482	—
Total	24,744,839	25,971,696	24,075,369	24,477,842	27,743,959	26,742,583

These figures, however, only imperfectly represent our supply imported to supplement our domestic production. There requires to be added the amount accruing from the importation of live animals for slaughter, dead or skin wools and hair, and the vast quantity of rags needed to swell the total required for the production of shoddy.

Bibliography.—J. Smith, 'Chronicum Rusticum Commerciale: or Memoirs of Wool' (London: 1747); 'Wool and Woollen Trade of Great Britain' (London: 1800); R. Bakewell, 'Observations on Wool' (London: 1808); J. Bischoff, 'History of the Woollen and Worsted Manufactures' (London: 1842); J. Yates, 'Textrinum Antiquorum' (London: 1843); T. Southey, 'Colonial Sheep and Wools' (London: 1852); J. James, 'History of the Worsted Manufacture in England' (London: 1857); M. Alcan, 'Traité du Travail de la Laine Cardée' (Paris: 1867); H. Carcenac, 'Des Textiles Végétaux et des Laines' (Paris: 1869); C. Leroux, 'Manufacture of Worsted and Carded Yarns' (Philadelphia: 1869); W. Smith, 'History of Morley, Yorkshire' (London: 1876); W. Youatt, 'Sheep' (2nd ed., London: 1878); Lorin Blodget, 'Textile Industries of Philadelphia' (Philadelphia: 1880); 'Textile Manufacturer' (Manchester: 1875-); 'Manufacturers' Review and Industrial Record' (New York).

(See Hair; Wool.) R. M.

INDEX.

ABACA (fibre), 983–5.
Abelmoschus esculentus (fibre), 961.
Abel's picric powder, 41, 902.
Abiarana (resin), 1694
Abies canadensis (tannin), 1985.
—— Cedrus (timber), 2014.
—— excelsa (resin), 1679–80, (timber) 2014.
—— Larix (tannin), 1993.
—— spp. (oil), 1431, (resin) 1624, 1686, (timber) 2021.
Abilla oil, 1414.
Abilo (resin), 1649.
Abobora oil, 1395.
Abroma augusta (fibre), 911.
Absinth, 217–9.
Absorption of plant-odours, 1456.
Abushahiri-bing (asafœtida), 1634.
Abuta rufescens (drug), 819.
Abutilon spp. (fibre), 911.
Acacia (potash), 255, (timber) 2012.
—— concinna (oil), 1360.
—— horrida (timber), 2015.
—— Julibrissin (coffee-shade), 716.
—— leucophlœa (fibre), 911.
—— spp. (resin) 1621, 1630–3, 1668, (tannin) 1982–3, 1986–7, 1993.
Acaciengummi, 1630–3.
Acajou, gommo, 1638.
Acarus on sugar-cane, 1869.
Accipenser Sturio (oil), 1376.
Aceite de Maria (copal), 1693.
—— palo (copaiba), 1640.
Acer pseudo-platanus (timber), 2021.
—— saccharinum (sugar), 1902–3, (timber), 2017.
Acetaniline, 658.
Acetates, 28–39.
—— acetic acid from, 21–5.
—— alumina, 28–9, 1295.
—— ammonia, 29–30.
—— characters, 28.
—— copper, 30–1, 1297.
—— iron, 31–2, 1299–1300.
—— lead, 32–4, 1300.
—— for defecating cane-juice, 1888.
—— lime, 34–6.
—— manganese, 36–7.
—— mercury, 37.
—— potassium, 37.
—— sodium, 37–8.
—— tin, 39.
—— zinc, 39.
Acetic acid, 5–39.
—— —— from alcohol, 6–7.
—— —— —— brandy vinegar, 23.
—— —— —— distillation of vinegar, 25–6.
—— —— —— dye- and tan-wood residues and sawdust, 15–19.
—— —— —— metallic acetates, 21–5.
—— —— —— paper pulp, 19.
—— —— —— waste products, 26.
—— —— —— wood, 7–15.
—— —— glacial, 21.
—— —— history, 6.
—— —— manufacture, 6–26.
—— —— properties, 6.
—— —— purification, 19, 23.
—— —— specific gravity, 5.
—— —— strength, 26–7.
—— —— testing, 26–8.
—— ether, 39.
Acetification, vinegar, 2040.
Aceto-arsenite copper, 31.
Aceto-chloride calcium, acetic acid from, 24–5.
Aceto-nitrate of chrome, 1296–7.
Acetone, 39.
Acetous fermentation, 6–7, 195.
Acetyl-phenyl-amine, 658.
Aceyta americana (resin), 1624.
Acheté, 1659, 1660.
Achillea spp. (oil), 1422, 1424.
Achras Balata, 1635–6, 1639.
Acid. acetic, 5–39.
—— arsenic, 663.
—— arsenious, 39–40.
—— carbazotic, 40–1, 680.
—— carbolic, 41–5, 671–84.
—— carbonic, 45–8.
—— carthamic, 865–6.
—— chlorhydric, 101–47.
—— chlor-oxy-naphthalic, 682.
—— chromic, 48.
—— citric, 48–50.
—— cresylic, 42.
—— gallic, 50.
—— hydrochloric, 101–47.
—— hydrofluoric, 147–8.
—— nitric, 148–60.
—— oxalic, 160–74.
—— phenic, 41–5, 671–84.
—— phthalic, 650, 682.
—— picramic, 680.
—— picric, 40–1, 680.
—— processes for purifying oils and fats, 1459–60.
—— pyrogallic, 51.
—— pyroligneous, 7–28.
—— (quantity of sulphuric) required for different raw phosphates, 1270.
—— rosolic, 680.
—— salicylic, 681.
—— sulpho-carbolic, 681.
—— sulpho-carbonic, 601–8.
—— sulphuric, 51–101.
—— tartaric, 174–90.
—— the term, 1.
Acidimetry, 1, 2, 3, 4, 5, 26, 27, 102, 103, 130, 131, 145, 148, 149.
Acidproof lute, 628.
Acids, fatty, table of, 1765.
Aconite, 791.
Aconitine, 230.
Aconitum heterophyllum (drug), 793.
—— Napellus (alkaloid), 230.
—— spp. (drug), 791.
Acorn-oil, 1415.
Acorus Calamus, 190, 1431.
Acouchi balsam, 1649.
Acrocomia sclerocarpa (oil), 1414.
Actæa racemosa (drug), 825.
—— spicata (drug), 812.
Actias silkworms, 1745.
Action of soap, 1792–4.
Actual densities of oils, tables of, 1649–70.
—— density test for butter, 1465.
Acuhiba wax, 1379, 2046.
Adam's apparatus (alcohol), 198.
—— bone-boiler, 1449–50.
—— drying-machine (bleaching), 494.
Adansonia digitata (fibre), 912, (resin) 1621.
Addi, 1675.
Adenanthera pavonina (oil), 1414, (resin) 1693.
Admont vitriol, 1297.
Adoxa Moschatellina (musk), 1525.
Adragante, 1685.
Adul oil, 1397.
Ægle Marmelos (drug), 793, (resin) 1693.
Ænocarpus spp. (oil), 1386.
Aerated waters, artificial, 365–77.
—— —— natural, 363–5.
—— —— [artificial] arrangement of factory, 375–6.
—— —— —— bottles, 376.
—— —— —— bottling - machines, 371–5.
—— —— —— corks, 376.
—— —— —— gas-holder, 369–70.
—— —— —— generalities, 376–7.
—— —— —— manufacture, 368–9.
—— —— —— mixing - machine, 370–1.
—— —— —— plain, 366.
—— —— —— purifier, 369.
—— —— —— saccharine, 367–8.
—— —— —— saline, 366–7.
African ammoniacum, 1630.
—— bdellium, 1636–7.
—— copal, 1640–4.
—— cubebs, 1814.
—— elemi, 1649, 1677.
—— (West) frankincense, 1649–50.
—— guanos, 1258–9.
—— kino, 1668.
—— rubbers, 1627–8, 1654–6.
—— tragacanth, 1686.
Agar, 1523–4, 1529, 1624.
Agaricus muscarius (narcotic), 1324.
—— olearius (oil), 1401.
Agathophyllum aromaticum, 1812.
Agati grandiflora (resin), 1693.
Agave americana (fibre), 913–6.
—— sisalana (fibre), 916–7.
—— vivipara (fibre), 917.
Agila (perfume), 1523–4.
Aglaia odorata (tea), 2010.
Agtstein, 1628–30.
Ailantus spp. (gum), 1693.
Air-injectors, 465.
Ajowan (drug), 791.
Ak (fibre), 934–8.
Akaroid resin, 1693.
Akyaw (perfume), 1523–4.
Alamodon spp. (pearl), 1517.
Alant, 810.
Alaun, 325–32.
Alaunerde, 332–3.
Albahaca oil, 1416.
Albizzia moluccana (coffee-shade), 716.
Albumen, 191–2, 1304, 2025.
Albumenized sensitive paper, 1540.
Alcanna spinosa (dye), 858.
Alcohol, 192–214, 2026–7.
—— distillation, 196–201.
—— fermentation, 194–6.
—— for sugar-refining, 1929–30.
—— from beet, 210–1.
—— —— grain, 206–10.
—— —— molasses, 203–6.
—— —— potatoes, 211–2.
—— —— wine, 201–3.
—— legislation, 214.
—— manufacture, 201–12.
—— oxidation (acetic acid), 25.
—— properties, 192–4.
—— rectification, 212–3.
—— sources, 193.
—— uses, 213–4.
Alcoholic fermentation, 194–5.
—— liquors, 217–29.
—— —— absinth, 217–9.
—— —— arrack, 219–20.
—— —— brandy, 220–2.
—— —— gin, 222–3.
—— —— kirschwasser, 224.
Alcoholic liquors, liqueurs, 224–7.
—— —— rack, 219–20.
—— —— rum, 228.
—— —— whisky, 228–9.
Alcoholometry, 214–7.
Aldehyde, 7, 229–30.
—— blue, 666.
—— green, 668–9.
Alder (acetic acid), 14–5, (gunpowder) 882–4, (timber) 2012.
Aleppische gallen, 1983–4.
Aleppo galls, 1983–4.
—— turpentine, 1686.
Alerce (fibre), 948, (timber) 2012.
Alerse wood, 2012.
Aletia argillacea (cotton-worm), 957.
Aleurites cordata (oil), 1411–2.
—— lacciferum (lac), 1668.
—— spp. (nut), 1352.
Alfa (fibre), 979–81.
Algarobilla, 1982.
Algarroba (copal), 1666.
Alhagi camelorum (drug), 818.
Alhambra bouquet, 1530.
Alizarine, 683–4.
Alkali for soap-making, 1767–8.
Alkalies, 230–318.
—— alkaline earths, 232.
—— alkaloids, 230–2.
—— ammonia, 232–50.
—— lithia, 250.
—— organic, 230–2.
—— potash, 250–79.
—— soda, 279–318.
Alkalimetry, 238, 239, 251, 254, 262, 277, 302, 306, 318–9.
Alkaline earths, 232.
—— pink mordant, 1296.
—— processes for purifying oils and fats, 1460.
Alkaloids, 230–2.
—— of tobacco, 1348–9.
Alkanet, 865
Alkanna tinctoria (dye), 855.
Alk awarwhal (gum), 1632.
—— tlah (gum), 1632.
Allégre still (alcohol), 202–3.
Alligator (oil), 1365, (musk) 1525, (skin) 1757.
Alligator-pear oil, 1415.
Allium sativum (oil), 1421.
—— spp. (oil), 1414.
Alloys, 319–25.
—— aluminium bronze, 320.
—— bell-metal, 320–1.
—— brass, 321–2.
—— bronze, 322–3.
—— German silver, 323.
—— gun-metal, 323.
—— Muntz's metal, 323–4.
—— pewter, 324.
—— solders, 324.
—— type-metal, 324–5.
Allspice, 1814, (oil) 1416.
Allumettes, 1277–93.
Almond-oil, 1377, 1416.
Almond [Java] oil, 1392.
—— [jungle] oil, 1396.
—— paste lute, 628–9.
—— soap, 1789.
—— wood, 2013.
Almonds, 1022.
Alnus glutinosa (tannin), 1993, (timber) 2012.
—— sp. (gunpowder), 882–4.
Aloe spp. (drug), 791–2, (dye) 855, (fibre) 917.
Aloes (drug), 791, (dye) 855, (oil) 1416, 2025.

Alosa Menhaden (oil), 1368.
Alpaca (hair), 1093, (tallow) 1375.
Alpinia Cardamomum, 1803–4.
—— officinarum (oil), 1421.
—— spp., 1808.
Alstonia spp. (drug), 810, (india-rubber) 1627, 1664.
Alstrœmeria Ligtu (starch), 1823.
Alta Vela phosphate, 1264.
Altingia excelsa (storax), 1683.
Alum, 325–32.
—— as a mordant, 1295.
—— ores, 327–8.
—— process of sugar-refining, 330–2, 1927–8.
—— rock, 326–7.
—— white, 1550.
Alumina, 332-3.
—— acetates, 28-30.
—— for defecating cane-juice, 1887.
—— mordants, 1295–6.
—— sulphate, 325.
Aluminate soda, 1296, 1787.
Aluminium acetate, 1295.
—— bronze, 320.
—— chloride (aqueous), 1296.
—— nitrate, 1296.
—— persulphate, 1295.
—— thiosulphite, 1296.
Amalgams, 333–4.
—— copper, 333.
—— gold, 333–4.
—— iron, 334.
—— silver, 334.
—— sodium, 334.
—— tin, 334.
—— zinc, 334.
Amanita muscaria (narcotic), 1324.
Amaranth spirit, 1302.
Ambaree (fibre), 961.
Amber, 1628–30, 2024, (oil) 1416.
Ambergris, 1524, (extract) 1528.
Amboyna kino, 1667–8.
Ambra, 1524.
Ambre, 1628–30.
—— gris, 1524.
Ambrina ambrosioides (tea), 2011.
American cedar-oil, 1419.
—— [South] copal, 1666.
—— double-shover stocks (leather), 1220.
—— (U.S.) guanos, 1258.
—— jute, 911.
—— keystone mill (leather), 1227.
—— lac, 1673.
—— liquidambar, 1682–3.
—— marten fur, 1031.
—— nutmeg, 1812.
—— nutmeg-oil, 1377.
—— [Central], pearl fisheries, 1520.
—— polecat fur, 1033.
—— red cherry (oil), 1382–3.
—— savin (oil), 1419.
—— turpentine, 1687–91.
—— union hide-splitter, 1233.
Amido-azo-benzol, 658.
—— naphthalene, 650.
—— toluol, 659.
Amidon, 1821-9.
—— de blé, 1828-9.
—— de riz, 1826–7.
—— grillé, 1645–7.
Amiru (olibanum), 1676.
Ammi copticum (drug), 791.
Ammonia, 232–50.
—— acetate, 29-30.
—— aqueous solution, 236.
—— carbonates, 239–43.
—— estimation, 247–50.
—— from bones, 243, 522.
—— —— combustion-gases, 233–4.
—— —— gas-liquor, 235.
—— —— peat, 243.
—— —— tar, 235.
—— ice-machine, 1137.
—— isopurpurate, 680.
—— picrate, 680.
—— pure solution, 238.
—— salts from bone, 522.
—— strengths, 238–9.
—— sulphate as manure, 1259.
—— sulphoricinoleate, 1304–5.
—— volcanic, 243–4.
Ammoniacal liquor, reduction of bulk, 241.
Ammoniacum, 793, 1624–6–7–30.
Ammoniakgummi, 1630.
Ammonium and tin chloride, 1303.
—— chloride, 244–6.
—— phosphate process for defecating beet-juice, 1849–51.
—— sulphate, 237–8, 246–7.
—— triphosphate from natural phosphates, 1851.
Ammoniuret of copper, 1297.
Amomum spp. (cardamom), 1804.
—— Zingiber (oil), 1421, (spice) 1809–10.
Amoora Rohituka (oil), 1414.
Amorpha canescens (tea), 2011.
—— fruticosa (dye), 858.
Ampelodesmos tenax (drug), 811, (fibre) 917.
Amygdalus communis (fruit), 1022.
—— gums, 1639.
—— spp. (resin), 1621.
Amylon, 1830.
Amyris elemifera (resin), 1625.
—— spp. (resin), 1623, 1649.
Anabas scandens (oil), 1375.
Anacardium-gummi, 1638.
—— occidentale (nut), 1352, (resin) 1621, 1638.
Anacyclus spp. (drug), 819.
Analysis, acetic acid, 26–8.
—— ammonia, 247–50.
—— animal charcoal, 1965–70.
—— beet-juice, 1952–5.
—— beetroot, 1955.
—— cane-juice, 1952–5.
—— clays, table, 1559, 1583.
—— glucose or starch-sugar, 1963–5.
—— hydrochloric acid, 146–7.
—— milk-sugar, 1970.
—— nitric acid, 159–60.
—— oils and fats, 1462–77.
—— pottery wares, table, 1558.
—— soap, 1792–9.
—— sugar, 1942–71.
—— sugar-cane, 1955–6.
—— tartaric acid. 184–9.
Anamirta spp. (drug), 808.
Ananassa sativa (fibre), 917–8, (fruit) 1027.
Anarrhicus lupus (oil), 1376.
Anas mollissima (down), 905.
Anchusa tinctoria (dye), 855.
Anda Gomesii (oil), 1414.
Andaquies wax, 2043.
Andiroba-oil, 1386.
Andromeda Leschenaultii (oil), 1432.
Andrew's tobacco machine, 1342–5.
Andromachia igniaria (fibre), 919.
Andropogon caricosus, 1984.
—— spp. (fibre), 919, (oil) 1419, 1422, 1423, 1429.
Anethum graveolens (oil), 1420.
—— spp. (drug), 810.
Angelica, 334, (oil) 1416.
Angora hair, 1095–7.
Angostura, 793, (oil) 1416.
Angræcum fragrans (perfume), 1528, (tea) 2010.
Anguay do guaiani, 1678.
Anguze-i-Lari (asafœtida), 1635.
Anhydrous nitric acid, 159.
—— sulphuric acid, 96–101.
Aniline, 655–7.
—— blacks, 671.
—— blue, 666.
—— browns, 669.
—— greys, 671.
—— isopurpurate, 680.
—— red, 660–2.
—— spirit, 1302–3.
—— yellows, 670.
Animal albumen, 191.
—— black, 452–3.
—— —— filters, 1922–3.
—— charcoal, analysis, 1965–70.
—— —— as manure, 1266.
—— —— filtration of beet-juice through, 1851–4.
—— fats, extraction of, 1447–51.
matter, cyanogen from, 270–1.
—— mordants, 1304.
—— oils and fats, 1361–1377.
—— —— —— blackfish, 1361.
—— —— —— bone, 1361.
—— —— —— butter, 1361–2.
—— —— —— butterine, 1362–3.
—— —— —— cod-liver, 1363–5.
Animal oils and fats, crocodile, 1365.
—— —— —— dugong, 1365.
—— —— —— egg, 1365–6.
—— —— —— herring, 1366.
—— —— —— horse, 1366.
—— —— —— houlican, 1366.
—— —— —— lard, 1366–7.
—— —— —— Malabar, 1367.
—— —— —— manatee, 1367–8.
—— —— —— menhaden, 1368.
—— —— —— miscellaneous, 1375–7.
—— —— —— neat's-foot, 1368.
—— —— —— niin, 1368–9.
—— —— —— porpoise, 1369.
—— —— —— sardine, 1369–70.
—— —— —— seal, 1370.
—— —— —— shark, 1370–1.
—— —— —— sod, 1371.
—— —— —— spermaceti, 1371–2.
—— —— —— tallow, 1372–3.
—— —— —— tunny, 1373–4.
—— —— —— walrus, 1374.
—— —— —— whale, 1374–5.
Animi, 1640–4, 1677.
Anise, 334–5, 1802–3.
—— [star] oil, 1417.
Aniseed, 334–5, 1802–3.
—— oil, 1414, 1416–7.
Anisette, 226.
Anjilli (timber), 2016.
Anjouan (resin), 1656.
Annatto, 855.
Annealing-ovens for glass, 1055–7.
Année, 810.
Anodonta herculea (pearl), 1517.
Anogeissus latifolia, 1647–8.
Anona squamosa, 919, 1668.
Anser spp. (oil), 1375.
Anstrichfarbe, 1552–6.
Antá (nut), 1357, (oil) 1376.
Ant-grease, 1375.
Anthemis spp. (drug), 798–9, 819.
Anthocercis spp. (narcotic), 1324.
Anthomyia betæ, 1835.
Anthon's method (starch-sugar), 1919–20.
Anthracene, 650–3.
Anthoxanthum odoratum (perfume), 1528.
Anthrapurpurine, 684.
Anthraquinone, 653.
Antiaris saccidora (fibre), 919.
Antichlor, 314.
Antimony, assay, 350.
—— detection, 347–8.
—— mordants, 1296.
—— potassium tartrate, 1296.
—— tartrate, 1296.
—— terchloride, 1296.
Antiseptics, 677.
Antiseptic soaps, 1789.
Aouara oil, 1411.
Ao-wu-su (spice), 1802–3.
Apatite, 1261.
Apeiba Tibourbou (oil), 1414.
Apfelwein, 414–21.
Aphis chinensis (galls), 1984.
Apiculture, 1127–30.
Apis spp. (honey), 1128–30, (wax) 2042–6.
Apium graveolens (oil), 1419.
Aplotaxis spp. (drug), 809–10.
Apocynum spp. (fibre), 919.
Apollinaris water, 363.
Apple (acetic acid), 14.
Apricot-oil, 1409.
Aptenopodites patagonica (oil), 1376.
Apteropasta segmentata (drug), 796.
Aquafortis, 148–60.
Aqua regia, 335.
Aquariums, lute for, 629.
Aqueous solutions (ammonia), 236–9.
Aquilaria Agallocha (drug), 791, (perfume) 1523–4.
—— spp. (resin), 1624.
Arabic gum, 1621, 1630–3, 2025.
Arabinose, 1830.
Arabisches gummi, 1630–3.
Arachis hypogæa (nut), 1357–8, (oil) 1391.
Araucaria spp. (resin), 1624, (timber) 2019.
Arbol a brea (resin), 1649.
Arbutus uva-ursi (drug), 794.
Arcanson, 1680–1.
Archangel tar, 1683.
Archangelica officinalis, 334, (oil) 1416.
Architectural pottery, 1582–7.
Arctium Lappa (oil), 1414.
Arctostaphylos spp. (drug), 794.
Areca, 793.
—— Catechu (drug) 793, (fibre) 919, (tannin) 1983.
—— nut, 1351.
—— palm fibre, 919.
—— spp. (oil), 1415.
Arenga saccharifera (fibre), 919, (starch) 1827, (sugar) 1904.
Argan-oil, 1377–8.
Argania Sideroxylon (oil), 1377–8.
Argemone mexicana (oil), 1409.
Argols, 174, 279, 335, 1303.
Aristolochia Serpentaria oil, 1432.
—— spp. (drug), 825.
Arjun trees (wax), 2045.
Armadillo skins, 1757.
Arnica, 793.
—— montana (drug), 793. (oil) 1432.
Arnotto, 855.
Aromatic vinegar, 335–6.
Arrac, 219–20.
Arree fibre, 921.
Arrowroot, 1822–3.
Arsenate sodium, 314.
Arseniate soda, 1296.
Arsenic, 336–40.
—— acid, 663.
—— assay, 357–8.
—— mordants, 1296.
—— orpiment, 339–40.
—— realgar, 340.
—— removal from sulphuric acid, 90–2.
—— white, 336–9.
Arseniksäure, 39–40.
Arsenious acid, 39–40, 336.
Arsenite, 40.
Arsenolite, 40.
Artanthe spp. (drug), 818.
Artemisia Absinthium (absinth), 217–9.
—— spp. (drug), 826–7, (oil) 1424, 1431, 1432.
Artichoke, 961.
Artificial gems, 1040–1.
—— ostrich plumes, 908.
—— waters, 365–77.
Artocarpus incisa (rubber), 1665, 1693.
—— integrifolia (as shade), 710–1, 714, 1812, 1815, (resin) 1624, 1628, 1668.
—— spp. (fibre), 919, (timber) 2016.
Aruba Island phosphate, 1264.
Arum spp. (starch), 1823.
Arundinaria macrosperba (paper), 1486.
Arundo saccharifera (sugar), 1860.
—— spp. (fibre), 919-20.
Arvation process for defecating cane-juice, 1888.
Asafœtida, 793, 1624, 1626, 1633–5, (oil) 1417.
Asagræa officinalis (drug), 798.
Asant, 1633–5.
Asarum europæum oil, 1432.
Asbestos, 340–1.
Asclepias pseudo-sarsa (drug), 823.
—— spp. (fibre), 920.
—— tingens (dye), 858.
—— Vincetoxicum (drug), 825.
Ash, determination of, in sugar 1946–7.
Ashantee pepper, 1814.
Ash-tree (acetic acid), 14, (potash) 255, (timber) 2012.
Asia Minor, opium in, 1309-11.
Asian (East), liquidambar, 1683.
Asparagus sarmentosus (drug), 793.
Asperula odorata (perfume), 1528.
Asphalt, 341–6, 2025.
—— boiling, 345.
—— casting 345.
—— extraction, 344–5.
—— preparation, 345.
—— sources, 341–4.
—— uses, 345-6.
Aspidium Filix mas (oil), 1414.
—— spp. (drug), 811.

Aspidosperma Quebracho (tannin), 1988.
Assai-oil, 1378.
Assaisonnements, 1802–17.
Assam-rubber, 1628, 1656–7.
—— sugar-cane, 1860.
Assaying, 346–60.
—— assay of guano, 358.
—— —— gunpowder, 359–60.
—— —— limestone, 360.
—— —— nitrate of potash, 360.
—— blowpipe, analysis, 346–7.
—— detection of metals, 347–9.
—— valuation of ores and metals, 349–58.
Assegal-wood, 2012.
Ass-skins, 1757.
Astelia spp. (fibre), 920.
Astragalus spp. (drug), 818, (resin) 1621, 1682, 1685.
Astrakan herring (oil), 1366.
Astrapœa cannabina (fibre), 948.
Astrocaryum acaule (oil), 1414.
—— spp. (fibre), 920.
—— vulgare (oil), 1411.
Atees, 793.
Atherosperma moschata (drug), 823, (oil) 1431, (spice) 1812.
Atlas silkworms, 1745.
Atomic weights, 361.
Atraphaxis spinosa (drug), 818.
Atropa Belladonna (alkaloid), 230–1, (drug) 794, (oil) 1414.
Atropine, 230–1.
Attalea Cohune (oil), 1414.
—— excelsa (resin), 1655, 1663.
—— funifera (fibre), 920, (nut) 1357.
Attar of roses, 1427–30.
Auchenia spp. (hair), 1093–4, (oil) 1375.
Aucklandia Costus (drug), 810.
Aurigpigment, 339–40.
Aurora shells, 1517, 1520.
Australian cabbage-palm (fibre), 946.
—— gum, 1621, 1632–3.
—— kino, 1668.
—— mallow (fibre), 963.
—— rubber, 1664.
—— pearl fisheries, 1518–9.
—— tobacco, 1334.
Autographic processes, 1608–10.
Auxiliary mills for sugar-cane, 1879.
Ava (narcotic), 1305.
Avens-oil, 1417.
Avicula margaritifera (pearl), 1517, 1519.
Axonge, 1366–7.
Azadirachta indica (resin), 1693.
Azaola Leerii (guttapercha), 1652.
Azuline, 680–1.
Azurine, 666.

BABUL (resin), 1632, (tannin) 1993.
Bacaba (oil), 1386.
Baccharis sp. (drug), 797.
Backhousia citriodora oil, 1432.
Bacon's multicolour press, 1605.
Bacterium putredinis, 1816.
Bactyrilobium Fistula (drug), 798.
Badger fur, 1030; grease, 1375.
Bael, 793.
Bagasse furnaces, 1876–7.
Bag filters, 651, 1889.
Bahamas pearls, 1520.
Bahia plassava, 920.
Balæna spp. (whalebone), 524–5, (oil) 1361, 1372, 1374–5.
Balænoptera spp. (oil), 1374–5.
Balam [various] (guttapercha), 1652.
Balanites ægyptiaca (oil), 1413.
Balao balsam, 1652.
Balata (gum), 1627, 1635–6, 1639.
Baldrian, 826.
Baleen, 524–5.
Baliospermum spp. (oil), 1387.
Balling twine, 1703–4.
Ballota nigra (oil), 1414.
Ball soda (soda), 289–95.
Balm of Gilead, 1623, 1636, (fir) 1686–7.
Balm-oil, 1417.
Balsam fir, 1686–7.
Balsamito, 1678.
Balsamocarpon brevifolium, 1982.
Balsamodendron spp. (resins), 1623, 1636–7, 1674–5.
Balsam of Acouchi, 1649.
—— —— vanilla, 1816.
Balsams (various), 1640, 1677–8.
—— detection of, 1624–7.
—— nature, &c., 1621–7.
Bamboo (fibre), 920–1, (paper) 1485–6.
Bambouk-butter, 1410.
Bambusa spp. (fibre), 920–1.
Bananas, 1022–3.
Banjawi (resin), 1637.
Bank-oil, 1368.
Baobab (fibre), 912.
Baptisia tinctoria (dye), 858.
Barbary gum, 1621, 1632.
Barberry, 794.
Barbotine, 826–7.
Barbus Chola (oil), 1375.
Barcelona nuts, 1358.
Bärentrauben, 794.
Barilla, 280.
Barium for defecating cane-juice, 1888.
Bark disintegrators, 1227.
Barkometer, 1229.
Bärlappsamen, 817.
Barley-sugar, 1831.
Barlow's kier (bleaching), 480.
—— type writer, 1608.
Barometer-tube, 1073.
Barosma betulina (camphor), 578.
—— camphor, 578.
—— spp. (drug), 795.
Barras, 1684.
Barwood, 855, 867.
—— spirit, 1303.
Baryta, 232, 361.
—— carbonate, 361.
—— green, 1548.
—— nitrate, 361.
—— sulphate, 361.
Barytsalpeter, 361.
Bas du fleuve, gomme du, 1631.
Basil (Holy) bouquet, 1530.
Basking shark (oil), 1370–1.
Bass brooms, 554.
Bassia butyracea (oil), 1408.
—— latifolia (oil), 1394.
—— longifolia (oil), 1392.
—— Parkii (oil), 1410.
—— spp. (oil), 1396, 1652, 1693.
Bassora gum, 1686.
Bastard aloe (fibre), 917.
—— cardamom, 1804.
—— cedar (fibre), 960.
Batavian sugar-canes, 1860.
Bate for dressing-leather, 1232.
Bat-grease, 1375.
Bath-evaporators, 1898.
Battery for hats, 1110,
—— of pans for cane-juice, 1890–1.
Batting pottery, 1578.
Bauhinia candida (oil), 1414.
—— spp. (shade), 714, (fibre) 921, (resin) 1693.
Baume de Chio, 1687.
—— —— Chypres, 1687.
—— —— copahu, 1639–40.
—— —— Giléad (faux), 1686–7.
—— —— Pérou, 1677–8.
—— —— San Salvador, 1677–8.
—— —— tolu, 1684–5.
—— du Canada, 1686–7.
Baum marten fur, 1031.
Baumöl, 1397–1406.
Baumwollensamenöl, 1385–6.
Bauxite, alum from, 330.
Bayberry-oil, 1417.
Bayee (bdellium), 1636.
Bay laurel [Californian] (oil), 1422–3.
—— oil, 1393, 1422.
—— salt, 1714–9, 1732–3.
Bdellium, 1623, 1624, 1626, 1636–7.
Beale's cement, 626.
Beaming jute, 1184–6.
—— machines (leather), 1232.
Bean-oil, 1378.
Bear (fur), 1030, (grease) 1375.
Bearberry, 794.
Beating esparto (paper), 1489.
Beaumontia grandiflora (fibre), 921.
Beaver fur, 1030.
Bedford coprolites, 1260–1.
Bedgery (narcotic), 1324.
Bedlamer oil, 1370.
Bedolee sutta (fibre), 986.
Beech (acetic acid), 14–15, (potash) 255, (oil) 1378, (tar) 1683, (timber) 2012–3.
—— marten fur, 1031.
Beecher's splint filling and cutting machines (matches), 1288–92.
Bee-culture, 1127.
—— hives, 1129.
Beer, 377–414.
—— barley, 378.
—— boiling, 396–8.
—— brewing, 379–411.
—— cooling, 399–401.
—— fermenting, 401–11.
—— hops, 378–9.
—— malting, 379.
—— mashing, 380–96.
—— vatting and fining, 411–4.
—— water, 377–8.
Beet, 1831–2.
—— alcohol from, 210–1.
—— analysis, 1955.
—— carrion beetle, 1835.
—— cleansing, 1836–7.
—— climate for, 1832–3.
—— composition, 1832.
—— cultivation, 1831–5.
—— diseases, 1835.
—— distillation (alcohol), 211.
—— enemies, 1835.
—— fly, 1835.
—— harvesting, 1834.
—— juice analysis, 1952–5.
—— —— concentration, 1854–7.
—— —— defecation, 1846–51.
—— —— depulpers, 1839.
—— —— extraction, 1837–46.
—— —— —— by diffusion, 1842–6.
—— —— filtration through animal charcoal, 1851–4.
—— —— lime scums, 1848–9.
—— —— maceration processes, 1839–42.
—— —— transport, 1836.
—— maceration (alcohol), 210–1.
—— manures for, 1833.
—— molasses, 1858–60.
—— —— carbonate potash from, 257–9.
—— —— chloride potash from, 266.
—— —— elution process for, 1859–60.
—— —— osmosis process for, 1858–9.
—— —— products from, 1858.
—— —— salts in, 1927.
—— —— sulphate potash from, 278.
—— pulp presses, 1838–9.
—— purchase, 1835–6.
—— rasping, 1837–8.
—— —— and pressing (alcohol), 210.
—— slices (exhausted), for cattle-food, 1845–6.
—— slicing-machine, 1843.
—— soil for, 1833.
—— sowing, 1833–4.
—— storing, 1834–5.
—— sugar, 1831–60.
—— —— ash, 1921.
—— —— yields, 1857–8.
—— washing, 1837.
Beetle-oil, 1375.
Beetling-machines (bleaching), 499–501.
Begass furnaces, 1876–7.
Bein, 521–5.
Beizen, 1293–1305.
Belladonna, 230–1, 794.
—— oil, 1414.
Belleek porcelain, 1596.
Bell-metal, 320–1.
Beluga spp. (oil), 1369.
Ben-nut oil, 1378–9.
Bengal cardamom, 1804.
—— kino, 1668.
—— quince, 793.
Benincasa cerifera (wax), 2046.
Benjamin, 1637–8.
Benjoin, 1637–8.
Benné-oil, 1388–90.
Bent-grass (fibre), 994.
Benzine, 1146, (spirit) 2026.
Benzoë, 1637–8.
Benzoin (resin), 1624, 1625, 1637–8, 2026, (oil) 1417.
Benzol, 647, 2026.
Berberin, 855–6.
Berberis spp. (drug), 794.
—— vulgaris (dye), 856.
Bergamot, 1025–6, (camphor) 578, (oil) 1417.
Bergera Königii (oil), 1410.
Berjot's machine (cider), 418.
Bernstein, 1628–30.
Berry's process (potassium ferrocyanide), 270–1.
Bertholletia excelsa (nut), 1351–2.
Bertramwurzel, 819.
Bessemer's sugar-cane press, 1878–9.
Beta spp. (sugar), 1831–2.
Betel, 793.
—— leaf (narcotic), 1305.
—— nut, 1351.
—— —— palm fibre, 919.
—— pepper (narcotic), 1305.
Betula alba (oil), 1417–8, (resin) 1624, (tar) 1684.
—— spp. (timber), 2013.
Beurre, 1361–2.
—— de cacao, 1379.
—— —— coco, 1383–4.
—— —— cocum, 1395.
—— —— muscade, 1396–7.
—— —— palme, 1406–8.
Beverages, 362–450.
—— aerated waters, 362–77.
—— beer, 377–414.
—— cider, 414–21.
—— cocoa, 421–2.
—— coffee, 422–3.
—— ginger-beer, 423–4.
—— lemonade, 424.
—— spruce-beer, 424–5.
—— tea, 425.
—— toddy, 425–6.
—— water, 426–32.
—— wine, 432–50.
Bhang (narcotic), 1305–6.
Bibiri (starch), 1823, (timber) 2015.
Bibliography, acidimetry, 5.
—— alkalimetry, 319.
—— chicory, 633.
—— coal-tar products, 684.
—— coffee, 722.
—— coral, 1523.
—— cotton manufactures, 790.
—— drugs, 827.
—— dyeing and calico-printing, 854.
—— dye-stuffs, 869.
—— electro-metallurgy, 881–2.
—— explosives, 903.
—— feathers, 909.
—— fibrous substances, 1000.
—— food preservation, 1022.
—— fruit, 1029.
—— fur, 1033.
—— gas, 1040.
—— gems, 1043.
—— glass, 1087.
—— hair, 1099.
—— honey and bees, 1130.
—— hops, 1131.
—— ice and freezing, 1142.
—— indiarubber manufactures, 1164.
—— ink, 1172.
—— ivory, 1176.
—— leather, 1239.
—— linen manufactures, 1255.
—— manures, 1277.
—— narcotics, 1351.
—— nuts, 1360.
—— oils, 1483–4.
—— paper, 1509.
—— pearl, 1523.
—— perfumes, 1532.
—— pottery, 1601.
—— printing and engraving, 1620.
—— resinous and gummy substances, 1695.
—— silk, 1747–8.
—— soap, railway-grease, and glycerine, 1802.
—— spices, 1817.
—— sponge, 1821.
—— starch, 1829.
—— sugar, 1976–7.
—— tannin, 1994.
—— tea, 2011.
—— timber, 2023.

Bibliography, vinegar, 2042.
—— woollen manufactures, 2112.
Bichloride tin (mordant), 1302.
Bichromate potassium, 266–7, (mordant) 1297.
Bichrome (mordant), 1297.
Bicubiba-wax, 1379, 2046.
Bienenwachs, 2042–4.
Biertumpfel's frame (candles), 592.
Bigarade, essence de, 1425.
Bignonia tomentosa (oil) 1415.
Bilsenkraut, 812.
Binary absorption ice machine, 1141.
Bindings, 1762.
Birch (acetic acid), 14–5, (oil) 1417–8, (tar) 1684, (timber) 2013.
Birch's scutcher and opener, 492.
—— sewing-machine, 472.
—— squeezer, 489.
Birkenöl, 1418.
Birkentheer, 1418.
Birnwein, 421.
Biscuit-ovens (pottery), 1563.
—— rubber, 1663.
Bish (drug), 791.
Bismuth, assay, 350.
—— detection, 348.
—— mordants, 1296.
Bison-hair, 1094.
Bissa-bôl (myrrh), 1674–5.
Bisulphate potassium, 279.
Bisulphite lime for defecating cane-juice, 1887–8.
Bitartrate potash (mordant), 1303.
Bitter-apple (drug), 808.
—— wood (drug), 820.
Bitume liquide, 1433–47.
Bitumen, 341–6.
—— extraction from schists by carbon bisulphide, 607.
Bixa orellana (dye), 855.
Bizam (perfume), 1524–6.
Biziura lobata (musk), 1525.
Black ash (soda), 289–95.
—— —— carbonating, 299–301.
—— —— lixiviation, 295–9.
—— boy resin, 1693, 2025.
—— cohosh, 825.
—— dammar, 1644–5.
—— filters, 1922–3.
—— fish-oil, 1361.
—— flux, 279.
—— irons (mordant), 1298.
—— kernel-oil, 1408.
—— liquor, 31–2, (mordant) 1299.
—— pepper, 1812–4.
—— pitch, 1679.
—— revivifying, 1923–6.
—— roots, 794.
—— snake-root, 825.
Blacking, 450–2.
Blacklead, 1087–93.
Blacks, 452–6.
—— animal, 452–3.
—— bone, 453–4.
—— Frankfort, 454–5.
—— ivory, 455.
—— lamp, 455–6.
Bladder-nut-oil, 1379.
Blair's kiln (sulphuric acid), 57.
Blaize revivifying kiln, 1854.
Blanc de baleine, 1371–2.
Blanchiment, 470–520.
Blast-furnace slag for glass, 1076.
Bleach house for calico printing, 477.
Bleaching, 470–520.
—— cotton, 471–508.
—— esparto, 1488–9.
—— generalities, 470–1.
—— linen, 515–8.
—— oils and fats, 1459–62.
—— ostrich plumes, 908.
—— powder, 456–70.
—— —— chambers or boxes, 459, 460–1.
—— —— characters, 456–7.
—— —— cost, 461.
—— —— gas mains, 459.
—— —— lime for, 459–60.
—— —— manganese ores for, 458.
—— —— manufacture, 457–70.
—— —— regenerating the manganese, 461–8.
—— —— replacing the manganese, 468–70.
—— —— stills, 457–8, 462, 466.
Bleaching powder, uses, 461.
—— —— yield, 461.
—— rags, 1492.
—— silk, 518–20.
—— starch, 1825.
—— woollen, 508–15.
Bleichen, 470–520
Bleichpulver, 456–70.
Bleizucker, 32–4.
Bleu de Mulhouse, 666.
—— de Paris, 666.
Blocking hats, 1114.
Block rubber, 1145.
Blood as manure, 1257.
Bloomers (leather), 1230.
Blowing engine, 465.
—— fur (hats), 1107.
—— lead-glass, 1069–70.
—— sheet-glass, 1066.
Blow-pipe analysis, 346–7.
Blubber, 1374–5.
Blue-irons (mordant), 1299.
—— mottled soap, 1787–8.
—— pigments, 1548.
—— from coal-tar, 664–7.
—— stone (mordant), 1297.
—— vitriol (mordant), 1297.
Blumea camphor, 577–8.
Blungers (pottery), 1559.
Bock's process (candles), 583–4.
Body-making of silk-hats, 1121–4.
Boegel & Gill's centrifugal, 1935.
Bœhmeria spp. (fibre), 921–32.
Boetius glass furnace, 1052.
Bogwood, 520.
Bohemian glass, 1067.
—— pearls, 1517.
Boiled salts, 1732.
Boiling esparto, 1486–7.
—— in vacuo, 1856–7, 1893–8.
—— oils, 1482, 2029–31.
—— rags, 1491–2.
—— straw, 1492.
—— sugar solutions, 1854–7, 1890–1900, 1906–7, 1911–2.
—— wood, 1493–4.
Bois amer, 820.
—— d'œuvre, 2012–23.
—— de santal citrin, 1527–8.
—— gentil, 818–9.
Boivin et Loiseau's process (sugar refining), 1930–3.
Bolax spp (resin), 1624.
Boldo, 794.
Boldoa fragrans (drug), 794.
Boma (nut), 1351, (oil) 1379.
Bombax Ceiba (fibre), 932.
—— Gossypium (resin), 1685.
—— malabaricum (for shade), 1815.
—— spp. (fibre), 932, (oil) 1414, (resin) 1621.
Bombay copal, 1641–2.
—— mastic, 1673.
Bonavist bean in sugar-cane culture, 1869.
Bonduc, 794.
Bone ash, 524, (manure) 1266, (pottery) 1561.
—— black, 453–4.
—— —— analysis, 1965–70.
—— commerce, 524.
—— composition, 521.
—— fat, 521, 1361.
—— —— extraction, 1448–50.
—— —— removal of lime from, 1460.
—— gelatine from, 522–4.
—— mills, 1256–7.
—— oil, 455, 1361, 1450, 1451.
—— purification of ammonia salts from, 522.
Bones, 521–4.
—— ammonia from, 243.
—— as manure, 1256–7.
—— uses, 521–2.
—— values, 524.
—— whalebone, 524–5.
Bonnefin's continuous preparator, 1898.
—— sugar-cane rasper, 1879.
Bonplandia trifoliata (drug), 793.
Boonti (starch), 1823.
Booth-Sawyer spindle (cotton manufactures), 763–4.
Boracic acid, 526, 533.
—— —— in Tuscany, 527.
Boracic acid, test for, 539.
Boracite, 526, 535.
Borassus flabelliformis (fibre), 932, (resin) 1693, (starch) 1827, (sugar) 1904.
Borates, 526, 533.
Borax, 526–41.
—— boracic acid, 527–31.
—— boracic minerals, 526–7.
—— Californian, 535–8.
—— commerce, 540–1.
—— in potassic salt beds, 531–3.
—— preparation of the imported articles, 539–40.
—— South American, 538–9.
—— test for boracic acid, 539.
—— tincal in Asia, 533–5.
—— uses, 540.
—— value, 540.
Bordeaux turpentine, 1687–91.
Borers of sugar-canes, 1869.
Boridsheh plant (resin), 1650.
Boring oil-wells, 1441–3.
Borneo camphor, 576–7.
—— rubbers, 1657–8.
Bornesite, 1830.
Boro-calcites, 526.
Bosch, 1362–3.
Bosphorus bouquet, 1530.
Boswellia, spp. (resin), 1623, 1636, 1676–7.
Botany Bay kino, 1668.
—— —— resin, 1693.
Bothriocephalus latus, 815.
Botryopsis platyphylla (drug), 819.
Bottle-corks, cement for, 623.
—— —— lute for, 629.
—— glass, 1075–7.
—— —— furnace, 1075.
—— making, 1076.
—— moulds, 1077.
Bottles, stoneware, 1573.
—— stoppering, 1074.
Bottling wine, 447–8.
Bouchard's machine (fibres), 925.
Bougies, 578–94.
Bouillon noir, 31–2.
Boulinikon, 1015.
Boulogne coprolites, 1261.
Bouquets, 1530–1.
Bourbon sugar-cane, 1860.
Bour's pan (cane-sugar), 1893.
Bouscaren's diffusion process (cane-sugar), 1880–1.
Boutons, 557–71.
Bower's apparatus (acetic acid), 15–18.
Bowl-spirit (mordant), 1302.
Bowstring-hemp, 995.
Box (timber), 2013.
Box-elder (sugar), 1903.
Boxing pines, 1687–9.
Box organ (cotton manufacture), 760.
Braby's (F.) process concentrating gas liquor, 241.
Brai, 1680–1.
Braids, 1762.
Brande's alcoholometer, 217.
Bran-drench for glove-kid, 1238.
Brandy, 220–2.
—— fictitious, 220–1.
—— vinegar, acetic acid from, 23.
Brass, 321–2.
—— lumps, 1297.
—— oil, 1407.
—— plating, 881.
Brassica spp. (oil), 1384–5, 1396, 1424, (spice) 1810.
Brauerpech, 1680.
Brayera anthelmintica (drug), 815.
Brazilian elemi, 1649.
—— nutmeg, 1812.
Brazil-nut, 1351–2, (oil) 1379–80.
—— wood, 856.
—— —— lake, 1549.
Bread-nut, 1352, (oil) 1406.
Breadthener (bleaching), 493.
Breaker-card for tow, 1251–2.
Breaking-down machine (gunpowder), 890.
—— machine for flax, 1246.
—— over hides, 1224.
Brechwurzel, 812.
Brevoordia Menhaden (oil), 1368.
Brewing, 379–414.
Brewing sugars, 1914–21, 1938–40.
Brianchon ware, 1599.
Briar (sweet) extract, 1528.
Brick-clay, 635.
Bricks, fire, 1570.
—— perforated, 1572–3.
Brighton green, 1549.
Brim-heater for hats, 1118–9.
Brimstone kilns (sulphuric acid), 52–3, 56–7.
—— lute, 629.
Brindonia tallow, 1395.
Brine, composition, 1729.
—— evaporating, 1724–40.
—— obtaining from rock-salt, 1725–40.
—— pans, 1714, 1728–39.
—— springs, 1719–24.
—— —— chloride potassium from, 265–6.
Brinjes' kiln for revivifying charcoal, 1924–6.
Bristles, 544, 1099.
—— vegetable, 919.
Bristol finishing (leather), 1231.
—— ware, 1599.
Britannia metal, 325.
British gum, 1645–7.
Broadleaf, 2013.
Broad-leaved ledum (narcotic), 1308.
Broke-paper, treatment of, 1494.
Bromelia Ananas (fibre), 917–9, (fruit) 1027.
—— karatas (fibre), 985.
—— spp. (fibre), 933.
Bromine, 541–2.
Bromo-, &c., caoutchouc wires, 1153.
Bronze, 322–3.
Broom (dye), 856, (fibre) 947.
—— corn, 542–3.
—— Spanish (fibre), 997.
—— tops (drug), 795.
Brosimium utile (resin), 1665.
Broussonetia papyrifera (fibre), 933.
Brosse, 543–57.
Brown Barbary gum, 1632.
—— kernel oil, 1408.
—— Windsor soap, 1789–90.
Browse Island guano, 1265.
Brucine, 231.
Bruges ribbon, 1529.
Brunswick green, 1549.
Brushes, 543–57.
—— bass brooms, 554–6.
—— commerce, 557.
—— compound stock, 545.
—— iron wire, 553–4.
—— materials for, 543–4.
—— round, 553.
—— simple flat, 544–5.
—— simple round, 544.
—— steel, 553.
—— with celluloid backs, 556–7.
—— Woodbury machine, 545–53.
Brushing machine (fibres), 914.
—— —— (hosiery), 1197–8.
Bruyere's cement, 626.
Bryonia callosa (oil), 1414.
Buchanan and Vickess kiln for revivifying charcoal, 1924.
Buchanania latifolia (oil), 1383, (resin) 1639.
Buchdruckerkunst, 1601–20.
Buchu, 795.
Buckingham Palace bouquet, 1530.
Buckthorn (acetic acid), 14, (drug) 795.
Buckwheat starch, 1823.
Buffalo robes, 1094, (skins) 1757.
Bugbane, 825.
Building cement, 626.
Buka, 795.
Bukowina phosphates, 1264.
Bul (borax), 534.
Bullet-tree (resin) 1635–6, 1639, (timber) 2013.
Bull-hoof, 1307.
Bundling flax yarn, 1254.
Bungo-tree and gum-resin, 1650.
Bun-raj fibre, 921.
Burbot-oil, 1364.
Burdock-oil, 1414.
Burgundy pitch, 1679–80.
Burmese lacquer, 1692.
Burners, brimstone, 52–3, 56–7.
—— pyrites, 80–7.

Burning earthenware, 1580.
—— points of oils, 1479–81.
Buro elachi (cardamom), 1804.
Bursera gummifera oil, 1432.
—— spp. (resin), 1623, 1649.
Burste, 453–57.
Busserole, 794.
Bussora gum, 1686.
Butea frondosa (oil), 1395.
—— spp. (dye), 867, (fibre) 933, (kino) 1668.
Butter, 1361–2.
—— analysis, 1464–6.
—— artificial, 1362–3.
—— preserving, 1016.
Butterine, 1362–3.
—— analysis, 1464–6.
Butter-nut-oil, 1379.
Butter-salt, 1732.
Butter-trees (oil), 1382, 1408, 1410.
Buttons, 557–71.
—— colouring, 562–3.
—— commerce, 571.
—— composition, presses, 564–6.
—— covered metal, 557–8.
—— —— —— machine for, 567–9.
—— glass, 559.
—— lathe, 566.
—— machinery, 560–9.
—— metal, 557.
—— mottling, 563.
—— moulds, 560.
—— pearl, 558–9.
—— polishing-machines, 560–2.
—— porcelain, 559.
—— seat of the industry, 571.
—— self-fastening, 569–71.
—— shirt, 559.
—— turned, 559–60.
—— turning-machines, 563–4.
Butts, shape of (leather), 1225–6.
Butua, 819.
Butyrospermum Parkii (oil), 1410.
Buxus spp. (timber), 2013.
Byrsonima spicata (coffee shade), 720.

CABLES, 1696–7.
Cabure-iba (resin), 1678.
Cacao, 684–91
—— butter, 1379.
Cachalot, 1371–2.
Cachou, 1982–3.
—— jaune, 1984–5.
Cactus Nopal (dye), 856–7.
—— spp. (resin), 1621.
Cadjii (gum), 1621, 1638.
Cadmium, assay, 351.
—— detection, 348.
Cæsalpinia Bonducella (drug), 794.
—— Cacalaco (tannin), 1993.
—— coriaria (tannin), 1983.
—— Sapan (dye), 867.
—— spp. (dye), 856.
Cajanus indicus for green-soiling sugar-cane, 1866, 1869.
Cajuput, 795, (oil) 1418.
Cake alum, 1295.
—— tobacco, 1342.
Calaba-oil, 1379.
Calabar-bean, 795.
Calabash nutmeg, 1812.
Calambak (coral), 1523–4.
Calamus Draco (cane), 595–8, (resin) 1648.
—— spp. (cane), 595–8.
Calcined copperas, 1298.
Calcium aceto chloride, acetic acid from, 24–5.
—— chloride from ammonia process, 241.
—— —— ulilization (bleaching powder), 468.
Caldera bush (fibre), 986
Caledonian queen sugar-cane, 1861.
Calender (bleaching), 498–9.
Calendering jute, 1185–6.
—— press (hosiery), 1197–8.
—— rubber sheets, 1149.
Calendula spp. (dye), 867.
Calf-kid (leather), 1237.
—— skins, 1757.
Calico-printing, 827–8, 835–54.
—— —— aniline black, 853.
—— —— application colours, 851–2.
Calico-printing, discharge style, 846.
—— —— general considerations, 835, 853–4.
—— —— indigo effects, 842–5.
—— —— machines, 836–40.
—— —— madder colours, 840–2.
—— —— manganese bronze style, 852.
—— —— padding style, 842.
—— —— pigment style, 852–3.
—— —— plate style, 842.
—— —— reserve style, 842.
—— —— spirit colour style, 851–2.
—— —— steam colours, 846–51.
—— —— thickeners, 836.
Californian bay laurel (oil), 1422–3.
—— nutmeg, 1812.
Callichroma moschata (musk), 1525.
Callitris quadrivalvis (resin), 1681, 1684, (timber) 2012.
—— spp. (resin), 1624, 1682.
Callorrhinus ursina (fur), 1032.
Calophyllum Calaba (oil), 1379.
—— spp. (oil), 1387–8, (resin) 1624, 1683, (timber) 2020, 2021.
—— tomentosum (oil), 1392.
Calotropis gigantea (drug), 818, (fibre) 933, (resin) 1627.
—— spp (fibre), 933–4.
Calumba, 795.
Calyptranthes caryophyllifolia (resin), 1693.
Calysaccion longifolium (perfume), 1526.
Cambridge coprolites, 1260.
Camel-hair, 1094.
Camelina sativa (fibre), 934, (oil) 1390.
Camellia Sasanqua (tea), 2010.
—— spp. (oil), 1411.
Cameraria latifolia (resin), 1665.
Cameras, 1534–5.
—— stands, 1536.
Cameroons oil, 1407.
Cammack & Walker's furnace (hydrochloric acid), 147.
Camphor, 571–8, 796, 1624.
—— barosma, 578.
—— bergamot, 578.
—— blumea or ngai, 577–8.
—— Borneo or Malay, 576–7.
—— Chinese, 573.
—— cinaebene, 578.
—— common, imitations, 574–5.
—— common or laurel, 572–6.
—— cubebs, 578.
—— definitions, 571–2.
—— Formosan, 572–3.
—— Japanese, 573–4.
—— neroli, 578.
—— oils, 578.
—— orris, 578.
—— patchouli, 578.
—— refining, 575–6.
—— sassafras, 578.
—— thyme, 878.
—— tobacco, 578.
Camphora officinarum, 571–6.
Camwood, 856, 867.
Canada balsam, 1624, 1686–7.
Canadian apatite, 1261.
—— turpentine, 1686–7.
Cananga odorata (oil), 1422.
Canari (for shade), 1811.
Canarium commune (oil), 1392, (resin) 1649, (shade) 1811.
—— spp. (resin), 1623, 1644–5.
Canary Islands' dragon's-blood, 1648.
Candle-nut, 1352, (oil) 1392–3.
Candles, 578–95.
—— coloured, 593–4.
—— combustible materials, 579–90.
—— dips, 591–2.
—— double wicks, 593.
—— fancy patterns, 593.
—— history and characters, 578–9.
—— illuminating values, 594.
—— manufacture, 591–4.
—— moulds, 592–3.
—— night-lights, 594–5.
—— ozokerit, 589–90.
—— palm-oils for, 583.
—— paraffin for, 586–9.
—— saponification, 579–82.
—— self-fitting ends, 593.
Candles, spermaceti for, 589.
—— tallow for, 579.
—— trimming and polishing, 593.
—— wax for, 586.
—— wicks, 590–1.
Cane, 595–8.
—— for paper, 1486.
—— glass, 1072.
—— juice analysis, 1952–5.
—— —— composition, 1871–3.
—— —— defecating, by chemicals, 1886–9.
—— —— —— by filtration, 1889–90.
—— —— —— by galvanism, 1890.
—— —— —— by heat, 1884–6.
—— —— —— by lime sucrate process, 1930–2.
—— —— defecation and clarification, 1884–90, 1930–2.
—— —— densities of, 1872.
—— —— extraction, 1873–83.
—— —— mineral matters in, 1872.
—— —— organic matters in, 1872–3.
—— —— tempering, 1886–7.
—— mills, 1873–5.
—— —— fuels for, 1876–7.
—— —— furnaces for, 1876–7.
—— slicing machines, 1880, 1881.
—— sugar, 1830, 1860–1902.
—— —— ash, 1921.
—— —— bleaching, 1900–1.
—— —— centrifugals, 1901.
—— —— characters, 1912–3.
—— —— claying, 1900.
—— —— concentration, 1890–1900.
—— —— curing, 1900–1.
—— —— determination, 1943–4.
—— —— diffusion process, 1880–3.
—— —— draining, 1900–1.
—— —— drying, 1900–1.
—— —— factory, 1902.
—— —— granulation, 1890–1900.
—— —— low, salts in, 1927.
—— —— occurrence, 1942–3.
—— —— solutions, table of sp. gr. of, 1952–5.
—— —— spirit-washing, 1900.
—— —— vacuum-chest for curing, 1901.
—— —— whitening, 1900–1.
—— —— yields of, 1870–1.
Canella, 796.
—— alba (oil), 1419.
Cannelle de Ceylan, 1805–7.
Canime (resin), 1649.
Canis spp. (fur), 1033.
Canna spp. (dye), 868, (starch) 1822.
Cannabis sativa (fibre), 934–8, (narcotic) 1305, (oil) 1391.
Cannon-ball mill, 1092.
Cantharides, 796–7.
Cantharis spp. (drug), 796–7.
Caouana divacca (oil), 1375.
Caoutchouc, 1142–64, 1627–8, 1654–66.
Cap lute, 629.
Cape gum, 1621, 1632.
—— lancewood, 2012.
—— mastic, 1674.
Capillair-syrup, 1920.
Capillary filters (sugar), 1889–90.
Capivi, 1639–40.
Capsicum, 797, 1803.
—— spp. (drugs), 797, (spice) 1803.
Capra spp. (hair), 1095–8.
Capraria biflora (tea), 2011.
Carabé (resin), 1628–30.
Carabus saponarius (oil), 1375.
Carama resin, 1649.
Caramania gum, 1686.
Caramel, 598–9.
Carana hedionda (resin), 1625.
—— resin, 1621–5, 1649.
Carapafett, 1386.
Carapa spp. (oil), 1386, 1395–6, 1432.
Carap-oil, 1386.
Caraque resin, 1649.
Caraway-oils, 1418–9.
Caraways, 1803.
Carbazotic acid, 40–1.
Carboleum for motive power, 46.
Carbolic acid, 41–5, 671–80.
—— —— characters, 671–2.
—— —— colourless crystallized, 676.
Carbolic acid, derivatives, 680–1.
—— —— distillation, 673–5.
—— —— early methods of manufacture, 672–3.
—— —— estimation in powders, 676.
—— —— impurities in, 676.
—— —— in dead oils, estimation, 676.
—— —— poisoning by, and antidotes, 676–7.
—— —— powders, 675–6.
—— —— present method of manufacture, 673–6.
—— —— purification, 675–
—— —— soap, 1789.
—— —— stills, 673.
—— —— tests for, 677.
—— —— tow, 676.
—— —— uses, 677.
Carbolsäure, 41–5, 671–80.
Carbon, 599–600.
—— bisulphide, 601–8
—— —— as a motor, 607–8.
—— —— characters, 601.
—— —— cost of manufacture, 608.
—— —— for extraction of bitumen from schists, 607.
—— —— —— —— seed-oils, 1454.
—— —— for recovery of waste grease, 605–6, 1155–6.
—— —— manufacture, 601–4.
—— —— statistics, 608.
—— —— uses, 604–8.
—— oxides, 45–8.
—— printing, 1540–1.
—— tissue, sensitizing, 1541.
Carbonates, 47–8.
—— ammonia, 239–44.
—— baryta, 361.
—— potassium, 253.
—— potash from felspar, 260.
—— —— from wine lees, 259.
—— sodium, 279.
Carbonating black ash (soda), 299 301.
Carbonation process for defecating beet-juice, 1846–9.
Carbonic acid, 45–8.
—— —— and carbonate of lime, table, 1969.
—— —— and lime process for defecating beet-juice, 1846–9.
—— —— tension, 46.
—— —— testing (sugar), 1847–8.
—— —— washing (sugar), 1847–8.
—— anhydride, liquefying, 46.
Carbonized wool, 2058–9.
Carboys (sulphuric acid), 101.
Carcharias melanopterus (oil), 1367.
Cardamom-oil, 1419.
Cardamoms, 1803–4.
Cardamomum majus, 1804.
Carding cotton, 743–9
—— engine for hatter's wool, 1103.
—— —— for tow, 1251–2.
—— jute, 1178–9.
—— wool, 2071–6.
Cardole, 1379.
Cards for cotton, 744.
Carduus pycnocephalus (oil), 1414.
Careya arborea (resin), 1693.
Carissa spinarum (resin), 1668.
Carius' ammoniacal solutions table, 239.
Carlina gummifera (resin), 1624.
Carlsbad water, 363–4.
Carludovica palmata (fibre), 938.
Carmaru-oil, 1379.
Carmes, eau des, 1532.
Carminated lake, 1549.
Carmine, 1549–50.
Carnallite, 262–3.
Carnauba palm (fibre), 940, (wax) 2044.
Carolina phosphate, 1263.
Caroline bouquet, 1530.
Carony, 793.
Carpathian balsam, 1687.
Carpet, 2095–2106.
—— designs, 2106.
—— looms, 2096–2105.
—— pile-yarns, 2105.
—— Worcester, 1101.
—— yarns, scouring and dyeing 2105–6.

Carpodinus sp. (resin), 1656.
Carrageen, 814.
Carrara water, 367.
Carré's continuous ice-machine, 1137.
—— sulphuric acid ice-machine, 1140.
Cartagena rubber, 1659–61.
Carthamic acid, 865–6.
Carthamus tinctorius (dye), 865–6.
Cartier's hydrometer, 215.
Carum Ajowan (drug), 791.
—— Carvi (oil), 1418–9, (spice) 1803.
—— nigrum (drug), 810.
—— petroselinum, 1425.
Carvi, fruits de, 1803.
Carya spp. (nut), 1358, (oil) 1391–2, (timber) 2015–6.
Caryocar brasiliense (oil), 1409.
—— spp. (oil), 1379.
Caryophyllus aromaticus (spice), 1807–8.
Caryota urens (fibre), 938, (starch) 1827, (sugar) 1904.
Casca, 823.
Cascalote (tannin), 1993.
Cascarilla, 797, (oil) 1419.
Case-hardened glass, 1079.
Caseine (cement), 626, (mordant) 1304, (varnish) 2025.
Cashew-apple-oil, 1379.
—— gum, 1638.
—— nut, 1352.
—— —— oil, 1379.
Cashmere goat-hair, 1097.
Cassava, 1828.
Casse, 1804–5.
Cassia, 798, 1804–5.
—— nuts, 1379.
—— occidentalis (coffee), 707.
—— oils, 1419.
—— spp. (drug), 798, 825, (resin) 1693.
Cassie satchet, 1531.
Castanea vesca (gunpowder), 884, (nut) 1352–3, (tannin) 1982, (timber) 2014.
Castanha-nut, 1351–2, (oil) 1379–80.
Castanospermum australe (nut), 1353.
Castilloa elastica (rubber), 1659–61.
—— Markhamia (rubber), 1659.
—— spp. (rubber), 1628.
Casting-house (glass), 1059.
Castnia elegans (resin), 1638.
Castor, 798, 1524.
—— fiber (drug), 798, (fur) 1030.
—— oil, 798, 1380–2.
—— —— plant for green-soiling sugar-cane, 1866.
Castoreum, 798, 1524.
Casuarina littorea (spice), 1807.
—— spp. (timber), 2018.
Catechu, 1982–3.
—— pale, 1984–5.
Catfish-oil, 1364.
Cat fur, 1030.
Catgut, 608–10.
Catha edulis (tea), 2010.
Cathartocarpus Fistula (drug), 798.
Cattell's guttapercha, 1164.
—— photo-engraving process, 1618.
Cattle-hair, 1095.
Cauline, 856.
Caustic potash, 251–3.
—— soda, 305–12.
Cavallium urens (resin), 1685.
Cavanillesia platanifolia (fibre), 938.
Cawdee (resin), 1666–7.
Cayenne pepper, 1803.
Cé tree (oil), 1410.
Ceanothus americanus (tea), 2011.
Ceara rubber, 1658–9.
Cebadilla, 798.
Cecropia peltata (narcotic), 1308, (resin) 1628, 1665.
Cedar, Australian red, 2013.
—— Bermuda, 2013–4.
—— boom, 2014.
—— extract, 1528.
—— New Zealand, 2014.
—— of Lebanon, 2014.
—— oil, 1419.
—— Virginian red, 2014.
Cedar, West Indian, 2014.
Cedrat cordial, 226.
—— essence, 1419.
Cedrela australis (timber), 2013.
—— odorata (timber), 2014.
—— Toona (resin), 1693, (timber) 2021.
Cedrus Deodara (resin), 1684, (timber) 2014.
—— Libani (oil), 1419, (timber) 2014.
Celastrus edulis (tea), 2010.
—— spp. (oil), 1414.
Celery-oil, 1419.
Cellier - Blumenthal's apparatus (alcohol), 198.
Celluloid, 610–8.
Celosia cristata (fibre), 938.
Celtis orientalis (fibre), 938, (resin) 1693.
—— Roxburghii (resin), 1668.
Cements, 618–31.
—— calcareous, 618–20.
—— cementing compounds, 623–8.
—— gelatinous, 620–2.
—— glutinous, 622–3.
—— lutes, 628–31.
Cemiostoma coffeelum (coffee), 699.
Cendres gravelées, 259.
Central American pearl fisheries, 1520.
—— —— rubbers, 1628, 1959–61.
Centrifugal machines, 495–6, 1825, 1839, 1901, 1934–5, 1937–8.
Century-plant (fibre), 912–6.
Cephaëlis Ipecacuanha (drug), 812–4.
Ceradia furcata (resin), 1624–5, 1693.
Cerambyx spp. (musk), 1525.
Ceramic photographs, 1543–4.
Cerasus gums, 1639.
Ceratonia siliqua (resin), 1668, 1671.
Ceratophorus spp. (resin), 1652, 1665.
Cerbera Manghas (spice), 1807.
—— spp. (oil), 1414.
Cerise, 663.
Ceroplastes ceriferus (wax), 2045.
Ceroxylon audicola (wax), 2046.
Cetonia aurata (drug), 796.
Cetraria islandica (drug), 812.
Ceylon pearl-fishery, 1517–8.
—— zimmt, 1805–7.
Chagual (gum), 1621, 1638.
Chakazi (copal), 1641.
Chalybeate water, 367.
Chamærops spp. (fibre), 938.
Chamber acid strength (sulphuric acid), 69.
Chamomile, 798, (oils) 1419.
Champonnois' beetroot pulp press, 1839.
—— potato-grater, 1824.
—— —— washer, 1824.
—— root-grater, 1824, 1838.
Chank, 1517.
Chapman's paper liquor evaporator, 1508.
Chapziger cheese, 1528.
Char analysis, 1965–70.
Charas (narcotic), 1305–6.
Charcoal, animal, 453–4.
—— —— as manure, 1266.
—— —— filters, 1851–4, 1889, 1922–3.
—— mill (gunpowder), 887.
—— patents, 1937.
—— retorts (gunpowder), 882.
—— revivification, 1853–4, 1923–6.
—— washing, 1852–3.
—— wood, 14–5, 882–4.
Char-dust as manure, 1266.
Charlestown phosphate, 1263.
Charlock-oil, 1396.
Chartreuse, 226–7.
Chasing porcelain, 1599.
Chatterton's compound, 1164.
Chaulmugra, 799, (oil) 1382.
Chavannesia esculenta (rubber), 1657.
Chavica spp. (narcotic), 1305, (spice) 1814.
Chay (dye), 856.
—— (guttapercha), 1652.
Cheese-salt, 1732.
Chelonia Cephalo (oil), 1375.
Chemical lute, 629.
Chemicking-machine (bleaching), 506, 515.
Chenaillier's evaporator, 1799.
Chenopodium ambrosioides (oil), 1432.
—— Quinoa (narcotic), 1308.
Chequito (oil), 1382.
Cherry (acetic acid), 14.
—— gum, 1621, 1638–9.
—— oil, 1382–3.
—— [Cornelian] oil, 1414.
Chestnut, 1352–3, 2014.
—— extract, 1226, 1982.
—— [horse] oil, 1392.
—— [Moreton Bay] (nut), 1353.
—— [Tahiti] (nut), 1353.
—— [water], (nut), 1359.
Chevé's tap (nitric acid), 157.
Chian turpentine, 1623, 1687.
Chickrassia tabularis (resin), 1693.
Chicle (gum), 1635, 1639.
Chicory, 631–3.
—— bibliography, 633.
—— characters, 631.
—— commerce, 632–3.
—— cultivation, 631–2.
—— preparation, 632.
—— uses, 632.
—— values, 632–3.
Chili saltpetre, 315–6.
Chillies, 1803.
Chimney-pots, 1573.
China (dye-stuff), 864.
—— 1594–7.
—— English, 1558, 1596–7.
China-clay, 635–9.
—— —— artificial, 639.
—— —— characters, 635.
—— —— cost of production, 638.
—— —— extraction and preparation, 636–8.
—— —— nature and utilization of waste products, 638–9.
—— —— occurrence, 635–6.
—— —— suggested improvements in preparing, 639.
—— —— uses, 638.
China grass, characters and uses, 930–2.
—— —— cultivation, 922–3.
—— —— extraction of the fibre, 923–30.
China-root, 799.
Chinchilla fur, 1030.
—— lanigera (fur), 1030.
Chinese cement, 623, 626.
—— galls, 1984.
—— green, 856.
—— pearl mussel, 1517, 1518.
—— silk, 1741–3.
—— sugar-cane, 1861.
—— varnish, 1692.
—— white, 1550.
—— white wax, 2044.
—— yellow rose extract, 1529.
Chios terpentin, 1687.
Chiretta, 799, 1805.
Chironia scabrida (oil), 1414.
Chironji (oil), 1383, (gum) 1639.
Chitrang (fibre), 997.
Chittagong wood, 2021.
Chloral, 633.
Chloranthus inconspicuus (tea), 2010.
Chlorate potassium, 261.
Chlorhydric acid, 101–47.
Chloride ammonium, 244–6.
—— calcium utilization (bleaching powder), 468.
—— copper, 1297.
—— lime, 456-70.
—— potassium, 261–6.
—— sodium, 1710–40.
—— sulphur for sugar-refining, 1929.
—— tin and ammonium, 1303.
Chlorine, 634.
—— and sulphur compounds for defecating cane-juice, 1888.
—— making without manganese, 468–70.
—— utilization (bleaching powder), 468.
Chlorkalium, 261–6.
Chlorkalk, 456–70.
Chlornatrium, 1710–40.
Chlorogalum pomeridianum (fibre), 939.
Chlorometry, 634–5.
Chloroxylon Swietenia (timber), 2021.
Chlor-oxy-napththalic acid, 682.
Chlorsäures kali, 261.
Chlorure, 456-70.
Chocho oil, 1395.
Chondodendron tomentosum (drug), 819.
Chondrus spp. (drug), 814.
Chop-nut, 795.
Chorisia speciosa (fibre), 939.
Chromate potassium, 266.
—— —— (yellow or neutral), 1297.
Chrome, 1297.
—— alum, 1297.
—— green, 1549.
—— yellow, 1551.
Chromic acid, 48.
Chromium, detection, 348.
—— mordants, 1296–7.
Chromograph, 1610.
Chromo-lithography, 1604–6.
Chromsäure, 48.
Chromsäures kali, 266.
Chrysanthemum Parthenium (oil), 1427.
—— spp. (tea), 2010.
Chrysobalanus Icaco (oil), 1414.
Chrysomela fastuosa (drug), 796.
Chrysophyllum ramiflorum (resin), 1693.
—— rhodeneurum (resin), 1652.
—— spp. (resin), 1665.
Churco (tannin), 1993.
Churrus (narcotic), 1306.
Chu tsale (borax), 534.
Chypre, eau de, 1532.
Cibotium Barometz (fibre), 939.
Cichorium Intybus (chicory), 631–3, (coffee) 707.
Cider, 414–21.
Cigarettes, 1345–6.
Cigars, 1344–5.
Cimicifuga racemosa (drug), 825.
Cinæbene camphor, 578.
Cinchona, 799–808.
—— alkaloids and their preparation, 804–6.
—— climate, 800.
—— collecting seeds, 800–1.
—— commerce, 807–8
—— cultivation, 800–4.
—— diseases, 803, 807.
—— distribution of the cultivation, 806–7.
—— harvesting the bark, 803–4.
—— layering, 802.
—— manuring, 803.
—— planting, 802–3.
—— plants, 799–800.
—— pricking out seedlings, 801.
—— propagation, 801–2.
—— removing and drying the bark, 804.
—— shading and staking, 803.
—— soil and drainage, 800.
—— spp. (alkaloid), 231, (drug) 799–808.
—— weeding and pruning, 803.
Cinchonine, 231.
Cingalese varnish, 1692.
Cinnamomum Camphora (camphor), 571–6, (drug) 796.
—— pedunculatum (wax), 2045.
—— spp. (oil), 1419, (spice) 1804–5.
Cinnamon, 1805–7.
—— Chinese, 1804–5.
—— oils, 1419.
Cirage, 450–2.
Circular stocking-frames, 1194–5.
Cire, 2042–6.
—— d'abeilles, 2042–4.
—— de bicuiba, 1379.
Cissampelos Pareira (drug), 819.
Cistus ladaniferus (drug), 818.
—— spp. (resin), 1624.
Citric acid, 48–50.
Citrometer, 49.
Citronella-oil, 1419–20.
Citron-oil, 1419.
Citronsäure, 48–50.
Citron-zeste, 1423.
Citrons, 1023.

Citrullus Colocynthis (drug), 808–9.
Citrus Aurantium (fruit), 1025–7.
—— Bergamia (oil), 1417.
—— Limetta (fruit), 1025.
—— Limonum (fruit), 1025.
—— medica (fruit), 1023.
—— spp. (camphor), 578, (drug) 816, (resin) 1677.
Civet, 1524, (extract) 1528.
Clam, 1517–1520.
Clapham's (R. C.) arrangement (hydrochloric acid), 116.
Clarification, cane-juice, 1884–90.
—— oils and fats, 1459–62, 2024.
Clark's indiarubber spreading- and doubling-machine, 1148.
Classification (wine), 440–1.
Claviceps purpurea (drug), 810–1.
Clawson's tobacco-weighing machine, 1346–7.
Clay, alum from, 329.
—— salt-pans, 1736–7.
Claying cane-sugar, 1900.
Clays, 635, 1558–60.
—— brick, 635.
—— china, 635–9.
—— fire, 639–40.
—— for terra-cotta and tiles, table of analyses, 1583.
—— meerschaum, 640.
—— pipe, 640.
—— pottery, 640.
—— table of analyses, 1559.
Clayton's roller adjusting gauge (cotton manufacture), 760.
—— tube roller (cotton manufacture), 743.
Cleaning silk, 1750–1.
—— sugar-beets, 1836–7.
Clear-boiling hard soap, 1779.
Cleome viscosa (oil), 1415.
Clerget's tables, sugar analysis, 1949–51.
Cloisonné ware, 1599.
Closing ropes, 1705–7.
Cloth-scouring, 512.
—— sulphuring (bleaching), 513.
Cloths for hatters, 1127.
—— [greasy], recovery of grease from, 605–6, 1455.
Clous de girofles, 1807–8.
Clove-bark oil, 1420.
—— nutmeg, 1812.
—— oil, 1420.
—— pink extract, 1529.
Cloves, 1807–8.
Clupea pontica (oil), 1366.
—— spp. (oil), 1369–70.
Clusia spp. (resin), 1693.
Cluster cardamom, 1804.
Coal, assay, 358.
—— brasses, 1297.
—— distillation, 1033.
—— gas, 1033.
—— shales, alum from, 328.
—— tar, ammonia from, 235.
—— —— creosote, 41.
—— —— distillation, 641.
—— —— oils, 641–84.
—— —— products, 641.
—— —— —— aniline blacks, 671.
—— —— —— —— browns, 669–70.
—— —— —— —— greys, 671.
—— —— —— —— yellows, 670–1.
—— —— —— anthracene, 650–3.
—— —— —— anthraquinone, 653–4.
—— —— —— benzol, 647–8.
—— —— —— bibliography, 684.
—— —— —— blue colouring matters, 664–7.
—— —— —— carbolic acid, 671–80.
—— —— —— —— —— derivatives, 680–1.
—— —— —— characters of tar, 641.
—— —— —— creosote, 648–9.
—— —— —— distillation of tar, 641–4.
—— —— —— greens, 668–9.
—— —— —— naphthalene, 649–50.
—— —— —— —— derivatives, 681–4.
—— —— —— nitro-benzols, -toluols, and -xylols, 654–64.
—— —— —— once-run naphtha, 644–7.
—— —— —— phenyl violets, 667–8.
Coal-tar, products, toluol, 648.
—— —— —— xylol, 648.
Coal-fish-oil, 1364.
Cobalt, assay, 351.
—— blue, 1548.
—— detection, 348.
Cob-nut [Kentish], 1358.
—— of Jamaica, 1352.
Coca, 1307–8.
Cocculus Chondodendron (drug), 819.
—— cordifolius (drug), 811.
—— indicus (drug), 808, (oil) 1383.
Coccus adipofera (oil), 1368–9.
—— cacti (dye), 856–7, (oil) 1375.
—— ceriferus (candles), 586.
—— Lacca (dye), 861–2, (lac) 1668.
—— manniparus (drug), 818.
—— oleæ (oil), 1401.
—— Pe-la (ink), 1170, (wax) 2044.
—— spp. (dye), 861.
Cochin China sugar-cane, 1861.
Cochineal, 856.
—— fat, 1375.
—— lake, 1550.
Cochlearia spp. (oil), 1432.
Cochlospermum Gossypium (oil), 1414, (resin) 1621, 1685.
Cockchafer-oil, 1375.
Cocoa, 421–2, 684–91.
—— bibliography, 691.
—— consumption, 690.
—— cost of production, 687.
—— cultivation, 686.
—— general considerations, 690.
—— guarana, 690–1.
—— local details, 687–90.
—— preparation, 686–7.
—— production and commerce, 686.
—— values, 690.
—— varieties, 685–6.
Coco-nut, 1353–7.
—— fibre, 939.
—— gum, 1621, 1639.
—— oil, 1383–4.
Cocos butter, 1383–4.
—— gummi, 1639.
—— nucifera (arrack), 219–20, (fibre) 939–40, (oil) 1353–7, (gum) 1621, 1639, (sugar) 1904.
Cocosnussöl, 1383–4.
Cocostalg, 1383–4.
Coction of hard soap, 1779.
Codd's filling machine (aerated waters), 371.
Cod-liver-oil, 1363–5.
Cœruline, 682.
Coffea spp. (beverage), 422–3, (coffee) 691–722.
Coffee, 422–3, 691–722.
—— adulterants and substitutes, 707.
—— bibliography, 722.
—— borer, 699.
—— bug, 699–700.
—— canker, 700.
—— catch-crops, 695–6.
—— commerce, 706–7.
—— consumption and prospects, 707.
—— dibbling, 694.
—— diseases and enemies, 698–700.
—— drying, 703–4.
—— estate, clearing and burning, 692–3.
—— —— drains, 695.
—— —— holing or pitting, 693.
—— —— lining, 693.
—— —— roads, 695.
—— —— selection, 692.
—— fermenting, 703.
—— fly, 698–9.
—— harvesting, 700.
—— hulling or peeling, 704.
—— in Ceylon, 709–12.
—— in India, 713–6.
—— in Liberia, 717.
—— in Natal, 718–9.
—— in the West Indies, 720–2.
—— leaf blight, 698.
—— leaves, 707.
—— local details of culture and production, 707–22.
—— manuring, 697–8.
—— nurseries, 691–2.
—— oil, 1407, 1420.
—— other methods of preparing, 705.
—— packing and shipment, 705.
—— planting, 693–4.
Coffee plants, distances, 693.
—— preparation, 700–5.
—— pruning, 696–7.
—— pulping, 700–3.
—— rot, 700.
—— shade, 695.
—— shelter, 694–5.
—— sizing, 705.
—— staking, 694.
—— stores, 704.
—— supplying vacancies, 694.
—— tools, 692–3.
—— varieties and values, 705–6.
—— weeding, 696.
—— winnowing, 705.
Coffey's still, 208, 246.
Cogan's process for purifying oils and fats, 1460.
Cohobator, 657.
Cohune-nut-oil, 1414.
Coing, 820.
Coir, 939.
Col, 1808.
Cola acuminata (nut), 1358–9.
Colchicum, 808.
—— autumnale (drug), 808.
Cold for concentrating cane-juice, 1900.
—— process of soap-making, 1771–3.
—— water soaps, 1789.
Coleman's machine (fibres), 924.
Cole-seed, 1384–5.
Collas stoning-machine, 1836–7.
Collodion emulsion, 1538.
—— processes, 1536.
—— (dry) processes, 1537–8.
Collograph, 1609.
Collotype printing, 1543.
—— processes, 1619–20.
Collyer's fibre-machine, 929.
Colocynth, 808.
Cologne, eau de, 1532.
Colombo, 795.
Colophane, 1680–1.
Colophonia mauritiana (resin), 1649.
Colophonium, 1680–1.
Colophony, 1680–1.
—— for soap-making, 1767.
Coloquintida, 808.
Colorado hemp, 919.
Coloured glass, 1083–4.
—— soaps, 1791.
—— windows, 1084.
Colouring esparto, 1490–1.
—— porcelain, 1599–1600.
Colour printing, 1604–6.
Columba migratina (oil), 1376.
Colza-oil, 1384–5.
Combretum butyraceum (oil), 1382.
Combing cotton, 747.
Combo oil, 1415.
Combs, 1132.
Common camphor, 572–5.
—— goat-hair, 1098.
—— iron (mordant), 1299.
—— turpentine, 1687–91.
Comparative table of lights, 1547.
Composing machines, 1601–2.
Composite salt-pans, 1736–7.
Compositions for matches, 1292–3.
Compressed gunpowder, 894.
Comptonia asplenifolia (tannin), 1993.
Concentrated alum, 1295.
Concentration beet-juice, 1854–7.
—— cane-juice, 1890–1900.
—— oxalic acid, 173.
—— sorghum-juice, 1911–2.
—— sulphuric acid, 92–6, 99.
Concha nacar (pearl), 1520.
Conch pearl, 1517, 1520.
Concretor (cane-sugar), 1898–1900.
Condensers, acetic acid, 12.
—— hydrochloric acid, 108–17.
—— nitric acid, 157–8.
Condiments, 1802–17.
Condy's process acetic acid, 24–5.
Conger-eel-oil, 1364, 1375.
Congo pea for green-soiling sugar-cane, 1866, 1869.
Conima resin, 1649.
Connarus spp. (oil), 1414.
Conocarpus latifolia (resin), 1647–8.
—— spp. (resin), 1651.
Construction of tanneries, 1228.
Consumption nitre (sulphuric acid), 79.
Convolvulus Purga (drug), 814–5.
—— Scammonia (drug), 823–4, (resin) 1624.
—— spp. (oil), 1430.
Cooawanoo-oil, 1375.
Coondi-oil, 1395–6.
Copahu, baume, 1639–40.
Copaiba, 809, 1623, 1624, 1625, 1639–40.
—— balsam-oil, 1420.
—— blanca, 1639.
Copaifera spp. (drug), 809, (balsam) 1623, 1639–40.
Copaiva, 1639–40.
Copal, 1623, 1624, 1625, 1626, 1640–4, 1666, 2024.
Copaubu-uçu, 1665.
Copernicia cerifera (fibre), 940, (wax) 2044.
Copper, acetate, 30, 1297.
—— —— acetic acid from, 23–5.
—— aceto-arsenite, 31.
—— amalgam, 333.
—— ammoniuret, 1297.
—— assay, 352.
—— chloride, 1297.
—— detection, 348.
—— engraving on, 1613.
—— mordants, 1297.
—— nitrate, 1297.
—— plates, facing with iron, 1613.
—— plating, 880.
—— sulphate, 1297.
—— wall for cane-juice, 1890–1.
Copperas, 1299.
Coppers, soap, 1774–5.
Coppersmiths' lute, 629.
Copra-oil, 1383–4.
Coprolites, 1260–1.
Coprosma Baueriana (coffee), 707.
Coptis, 809.
—— spp. (drug), 809, (dye) 856.
Copying-inks, 1166.
—— processes, 1608–10.
Coquilla-nut, 1357.
Coquita (fibre), 962.
Coquito-oil, 1385.
Corall, 1521–3.
—— des jardins, 1803.
Coral, 1521–3.
—— bibliography, 1523.
—— imports, 1523.
Coralline, red, 680.
—— yellow, 680.
Corallium rubrum, 1522.
Corchorus spp. (fibre), 940–5.
Cordage, 1695–1710.
—— hand-made, 1696–7.
—— machine-made, 1697–1704.
Corde de boyau, 608–10.
Cordia globosa (tea), 2011.
—— Rothii (resin), 1693.
—— spp. (fibre), 945.
Cordillera wax, 2044.
Cords, 1696, 1762.
Cordyline spp. (fibre), 945–6.
Coriander, 1808, (oil) 1420
Coriandrum sativum, 1420, 1808.
Coriaria myrtifolia (tannin), 1988.
—— ruscifolia (tannin), 1993.
Cork, 722–9.
—— carpet, 1015.
—— commerce, 728–9.
—— cutting, 725–7.
—— disintegrator, 727.
—— flattening, 724.
—— grinding, 727–8.
—— history, 728.
—— stripping, 723–4.
—— uses, 724.
Corkwood cotton, 986.
Cornelian cherry oil, 1414.
Cornish stone, 1560.
Cornstalk-sugar, 1908–14.
Corn-starch, 1823, 1828–9.
Cornus florida (timber), 2015.
—— mascula (oil), 1414.
—— sanguinea (oil), 1388.
Corozo-nut, 1357.
Corps gras, 1360–1484.
Corragine (fibre), 994.
Corrosion of metals by oils, 1481.
Corticine, 1015.
Corylus spp. (gunpowder), 884, (nut) 1358.

Corypha cerifera (wax), 2044.
—— Gebanga (starch), 1827.
—— spp. (fibre), 946.
Coscinium fenestratum (dye), 856.
Costus, 809.
Coto, 809.
Cotoneaster nummularia (drug), 818.
Cotton, 948–60.
—— bleaching, 471–508.
—— —— bleach house, 477.
—— —— kiers, 477–8, 480.
—— —— limeing and chemicking machines, 478–80.
—— —— madder bleach, 471–94.
—— —— market bleach, 495–506.
—— —— Turkey red bleach, 494.
—— —— yarn and thread bleaching, 506–8.
—— carding, 743–7.
—— cards, 744.
—— characters and uses, 959.
—— combing, 747–9.
—— commerce, 786, 959–60.
—— cultivation, 954–7.
—— distribution, 948–54.
—— doubling, 764.
—— drawing, 749.
—— drawing-in, 779.
—— dyeing, 828–35.
—— —— blacks, 828–9.
—— —— blues, 829–30.
—— —— browns, 830–1.
—— —— drabs, 831.
—— —— greens, 831.
—— —— greys, 831–2.
—— —— mechanical appliances, 835.
—— —— oranges, 832.
—— —— reds, 832–4.
—— —— violets, 834.
—— —— yellows, 834–5.
—— fibre: its structure in relation to manufacture, 731.
—— gasing, 765.
—— ginning, 957–9.
—— grass, 948.
—— insects, 957.
—— length of staple, 732.
—— looms, 781.
—— manufactures, 729–90.
—— —— bibliography, 790.
—— —— commerce and statistics, 786–90.
—— —— generalities, 729–30.
—— manures, 957.
—— mill, 734.
—— mixing, 737.
—— opening, 739.
—— polishing, 765.
—— powder, 897.
—— reeling, 764.
—— roving, 752.
—— scutching, 741.
—— seed-oil, 1385–6.
—— separation of the fibre, 957–9.
—— sizing, 766, 770.
—— slubbing, 751.
—— spinning, 733–66, 753–64.
—— twisting-in, 779.
—— warping, 769–70, 777–9.
—— weaving, 766, 780.
—— —— shed, 767.
—— winding, 766, 768, 777.
—— yarn and thread bleaching, 506–8.
—— yarns, 738.
Cotton's hose-machine, 1193.
Couepia dulcis (oil), 1414.
Cougle for hats, 1127.
Coula edulis (oil), 1414.
Coumarine, 1528.
Coumarouna odorata (perfume), 1528.
Coumu-oil, 1386.
Country mallow (fibre), 911.
—— walnut, 1352.
Coupier's reds, 663.
Court bouquet, 1530.
Covered metal buttons, 557.
Cowdee (resin), 1666–7.
Cow-hair, 1095.
—— hides, 1758.
Cowrie wood, 2016.
Cow-tree (gum), 1664, 1693.
Crab-oil, 1386.
Crabbing-machine (bleaching), 512.
Crackle-glaze, 1598–9.
Crandall type-writer, 1608.
Cratæva Marmelos (drug), 793.
Cream of tartar, 189, 1303.
Creasote, 1683.
Creosote, coal-tar, 41, 648.
Cresol, 42.
Cress-oil, 1415.
Cresylic acid, 42.
Cricetus vulgare (fur), 1031.
Crighton opener, 739.
—— scutcher, 741.
Crimson spirit, 1303.
Crinum spp. (drug), 826.
Crocodile musk, 1525.
—— oil, 1365.
Crocus sativus (dye), 866–7, (oil) 1430.
Crotalaria spp. (fibre), 946–7.
Croton Draco (resin), 1648.
—— Eluteria (oil), 1419.
—— lacciferum (resin), 1668.
—— moluccanum (nut), 1352.
—— oil, 809, 1386–7.
—— philippinensis (dye), 861.
—— sebifera (oil), 1412.
—— spp. (drugs), 797–8, (oil) 1387, (resin) 1668.
—— Tiglium (drug), 809, (oil) 1386–7.
Crown glass, 1057.
—— —— manufacture, 1063.
—— sewing silk hats, 1126.
Crucible, Hessian, 1558.
Crucibles, 790, 1570.
—— for glass, 1046.
—— lute for, 629.
Cruciferæ (oil), 1421.
Crude naphtha, 1446.
Crushing machine (fibres), 912.
—— mineral phosphates, 1267–8.
—— sugar-cane, 1873–5.
Crust-guanos, 1264.
—— roans (leather), 1236.
Crutching soap, 1785–6.
Cryolite, alum from, 330.
Cryptocarya moschata, 1812.
Cryptomorphite, 527.
Cryptostegia grandiflora (fibre), 947, (resin) 1655, 1664.
—— spp. (resin), 1627.
Crystallizable sugar, determination, 1943–4.
—— —— in cane-juice, 1871–2.
Crystallizing-points of saltpetre solutions, 277.
Crystallization of sugar, 1849–50, 1854–5, 1893.
Cuaxinduba (resin), 1665.
Cuba bast, 962.
Cubeba Clusii (spice), 1814.
—— spp. (drug), 809.
Cubebs, 809.
—— African, 1814.
—— camphor, 578.
—— oil, 1420.
Cubic alum, 1295.
Cuca (narcotic), 1307.
Cucumber-oil, 1395.
Cucumis Melo (sugar), 1903.
—— spp. (drug), 808–9, (oil) 1395.
Cucurbitaceæ (oil), 1395.
Cudbear, 864.
Culen tea, 2011.
Cultivation, aloes, 792.
—— beet, 1831–7.
—— chicory, 631–2.
—— China grass, 922–3.
—— cinchona, 800–4.
—— cocoa, 686.
—— coffee, 691–700.
—— cotton, 954–7.
—— esparto, 979–80.
—— flax, 965–7.
—— hemp, 934–5.
—— indigo, 858–61.
—— jute, 941–2.
—— Manilla hemp, 983.
—— phormium, 987–8.
—— sorghum, 1909–10.
—— sugar-cane, 1860–70.
—— sumach, 1988–90.
—— sunn hemp, 946.
—— tea, 1994–8.
—— wattles, 1986–7.
Cumbi resin, 1648.
Cumin, 809, (seed-oil) 1415.
Cuminum Cyminum (drug), 809–10.
Cumol, 2026.
Cunningham's flax-hackling machine, 1246.
Cup and cone hardener (hats), 1106.
Cupania sideroxylon (oil), 1394.
Cupressus sempervirens (timber), 2014.
Curaçoa (liqueur), 227.
—— phosphate, 1264.
Curari, 810.
Curcas purgans (nut), 1359, (oil) 1410, (resin) 1694, (shade) 1815.
Curcuma longa (dye), 868.
—— spp. (oil), 1432, (starch) 1822.
Curcumin, 868.
Curd cement, 627.
—— soaps, 1779.
Curdee-oil, 1410.
Curing indiarubber, 1154.
—— soap, 1783.
—— sugar, 1857, 1900–1.
—— telegraph cores, 1152.
—— water-proofed fabrics, 1149.
Curling hair, 1100.
Currajong fibre, 994.
Currants, 1023.
Curratow fibre, 933.
Curry-leaf tree (oil), 1410.
Currying leather, 1234.
Curtisia faginea (timber), 2012.
Curvamboo (resin), 1693.
Cusparia, 793.
—— trifoliata (drug), 793.
Cusso, 815.
Cutch, 1982–3.
Cutlers' cement, 623.
Cutting glass, 1074.
—— machines (paper), 1603–4.
—— —— (rubber valves), 1150.
—— paper, 1503–5.
—— rags, 1491.
—— soap, 1781–3.
—— straw, 1492.
Cuvelier's beetroot pulp press, 1839.
Cyanide potassium, 267.
Cyankalium, 267.
Cyanogen from animal matter, 270–1.
Cyanotype, Herschel's, 1617.
Cycas circinalis (resin), 1693.
—— spp. (starch), 1827.
Cyclopia genistoides (tea), 2010–1.
Cydonia vulgaris (drug), 820.
Cylicodaphne spp. (oil), 1415.
Cylinders, hydrochloric acid, 104–9.
—— moulding (glass), 1066.
Cymbopogon spp. (oil), 1429.
Cymogene, 1446.
Cynanchum ovalifolium (resin), 1657.
—— viminale (resin), 1624.
Cynips Gallæ tinctoriæ (tannin), 1983–4.
Cynometra spp. (oil), 1414.
Cyperus esculentus (oil), 1414.
—— spp. (fibre), 947.
Cypress, 2014.
Cyprian turpentine, 1687.
Cypripedium pubescens (drug), 825.
Cyprischer terpentin, 1687.
Cyprus satchet, 1531.
—— vitriol, 1297.
Cysteodemus armatus (drug), 797.
Cystophora cristata (oil), 1370.
Cytisus scoparius (drug), 795, (dye) 856, (fibre) 947.

DACRYDIUM cupressinum (resin), 1680.
—— spp. (timber), 2019.
Dacus oleæ, 1400.
Dæmia extensa (fibre), 947.
Dæmonorops spp. (cane), 595–8, (resin) 1624.
Daglish's blowing-engine, 465.
—— kilns, 83.
—— still, 36.
Dahlia, potash from, 255.
—— purpurea (oil), 1432.
Dairy produce preservation, 1016.
Dalbergia nigra (timber), 2020.
—— Sissu (timber), 2021.
Dalbergia spp. (resin), 1668.
Dalican's tallow test, 1477.
Dallas' photo-engraving process, 1618.
Damar, 1644–5.
Dambonite, 1830.
Dambose, 1830.
Dames' violet oil, 1414.
Dammar, 1623, 1624, 1625, 1644–5.
—— austral, 1666–7.
—— de la Nouvelle-Zélande, 1666–7.
—— selo, 1668.
—— white, 1678.
Dammara australis (timber), 2016.
—— spp. (resin), 1624, 1644, 1666–7.
Damping-machine (bleaching), 497.
Dancer's aspirator, 129.
Dandelion, 826.
Dandy furnaces, 117–8.
Daniellia thurifera (resin), 1649–50.
Daphne Mezereum (oil), 1414.
—— spp. (drug), 818–9, (fibre) 947.
Dark room (photography), 1536.
Darmsaite, 608–10.
Dash-wheels (bleaching), 495.
Date palm (fibre), 986.
—— tree sugar, 1904–8.
Dates, 1024.
Datura spp. (drug), 826, (narcotic), 1325.
Daucus Carota (oil), 1432.
Dawamese (narcotic), 1307.
Day's indiarubber substitute, 1162.
Deacon's furnace (soda), 284.
Deadly nightshade, 794.
Deal (acetic acid), 15.
—— white, 2014.
Debregeasia spp. (fibre), 947.
Déchet de lait, 1903–4.
Deckanee hemp, 961.
Decolorizing oils and fats, 1461–2.
Decorative processes (pottery), 1597–1601.
Deer skins, 1757.
Defecation, beet-juice, 1846–51.
—— cane-juice, 1884–90.
—— —— —— by chemicals, 1886–9.
—— —— —— by filtration, 1889–90.
—— —— —— by galvanism, 1890.
—— —— —— by heat, 1884–6.
—— —— —— lime sucrate process, 1930–2.
—— sorghum-juice, 1912–3.
Defibrating sugar-canes, 1878.
Dégras for currying, 1235.
De la Bastie's toughened glass, 1079.
Delphinapterus leucas (oil), 1369.
Delphinium Staphisagria (drug), 826.
Delphinus spp. (oil), 1369, 1372.
Demerara yellow crystals, 1894–5.
—— —— —— defecation for, 1888–9.
De Mornay cane-mill, 1875.
Dendrocalamus spp. (fibre), 921.
Deniering silk, 1753–4.
Densimeter (gunpowder), 895–6.
Dental rubbers, 1154.
Deodar wood, 2014.
Deodorizers, 677.
Deodorizing oils and fats, 1461.
Depazea maculosa (coffee), 700.
—— sacchari on sugar-cane, 1869–70.
Depilatories, 1220–4.
Depulpers for beet-juice, 1839.
Dérayage of leather, 1234.
Designolle's powder, 41.
Detection [mutual], fatty-oils, 1469–71.
—— oils and fats, 1462–77.
—— resins, gum-resins, and balsams 1624–7.
Deterioration (wine), 447.
Detonators, 903.
Developing recipes, 1537.
Devil's cotton, 911.
Dextrine, 1645–7.
—— transformation into sugar, 1914–5.
Dextrose, 1830, 1831.
Dhak kino, 1668.
Dhauri, 858.
Dhoura gum, 1647–8.
Dhunchee (fibre), 996.
Diabetic sugar, 1830.
Diablotin (oil), 1376.
Diamond, 1041.

Di-amyl-aniline, 658.
Diaphragms, 1533–4.
Diaspore, 332.
Dibromanthraquinone, 653.
Dichopsis spp. (rubber), 1627, 1652–4.
Dicypellium caryophyllatum (oil), 1420, (spice) 1808.
Didthin (resin), 1674.
Di-ethyl-aniline, 657.
Dietrich's (F.) process (tartaric acid), 180.
Diffusion process, beet molasses, 1858–9.
—— —— extracting beet-juice, 1842–6.
—— —— —— cane-juice, 1880–3.
Digitale, 811.
Digitalis spp. (drug), 811.
Dihl's lute, 629.
Dika-fat, 1387.
Dika-mali (resin), 1624, 1648.
Dill, 810, (oil) 1420.
Dilo-oil, 1387-8.
Diospyros glutinosa (resin), 1684.
—— spp. (timber), 2015.
—— virginiana (timber), 2019.
Diphenylamine, 658.
—— blue, 666.
Di-phenyl-rosaniline, 667.
Diplarrhena Moræa (fibre), 948.
Diplolepis Gallæ tinctoriæ (tannin), 1983–4.
Dippel's oil, 1361.
Dipping-frame for matches, 1279.
—— matches 1281.
Dipsacus fullorum, 2084.
Dipterocarpus spp. (drug), 812, (resin) 1624, 1651–2, (timber) 2016.
Dipteryx spp. (oil), 1379, (perfume) 1528.
Dip turpentine, 1688.
Disinfectants, 677, 790.
Disinfecting powders, 44.
—— soaps, 1789.
Disintegrating sugar-canes, 1878–9.
Disintegrators, bark, 1227.
Diseases, cinchona, 803, 807
—— coco-nut, 939.
—— coffee, 698–700.
—— cotton, 957.
—— olive, 1400–1.
—— sugar-beets, 1835.
—— sugar-canes, 1868–70.
—— tea, 1997.
—— tobacco, 1330.
Diss, 917.
Dissolving rubber, 1147.
Distillation, absinthe, 218–9.
—— acetic acid from vinegar, 25–6.
—— alcohol, 196–201, 202–3, 205, 206, 208–9, 212–3.
—— ammonia, 234.
—— aniline, 656.
—— beet (alcohol), 211.
—— carbolic acid, 673–5.
—— coal, 1033–4
—— coal-tar, 42–3, 641–4.
—— essential oils, 1457–8.
—— hydrochloric acid, 147.
—— lime acetate, 34–6.
—— liqueurs, 225–6.
—— marine plants (potash), 264–5.
—— mineral acetates (acetic acid), 21–5.
—— naphtha, 645.
—— nitro-benzol, 655.
—— paraffin, 1510–4.
—— petroleum, 1446–7.
—— rosaniline, 660.
—— wood (acetic acid), 7–21.
Dita, 810.
Di-toluyl-amine, 658.
Divi-divi, 1226, 1983.
Djamba (narcotic), 1306.
Djave fat, 1396.
Dobson and Barlow's cotton-gin, 958.
Docimasie, 346–60.
Dœmatium monophyllum (oil), 1401.
Doffing (cotton manufacture), 761.
Dog-grease, 1375.
Döggut (oil), 1418.
Dogwood, 2015.
—— black (gunpowder), 882–4.
—— oils, 1388.
Dole's tallow-renderer, 1447.
Dolichos Lablab, 1869.
—— spp. (fibre), 948.
Dolly (bleaching), 514.
Domba-oil, 1387–8.
Dombeya cannabina (fibre), 948.
Donkey sewing-machine, 471.
Doornboom (resin), 1632, (timber) 2015.
Dorema Ammoniacum (drug), 793, 826.
—— spp. (resin), 1624, 1630.
Dorse-oil, 1364.
Doryphora Sassafras (drug), 823.
Double carbonatation for defecating beet-juice, 1846–9.
—— muriate of tin, 1301.
—— shover stocks, 1220.
—— still (alcohol), 206.
—— transfer prints, 1542.
Doubling cotton, 764.
—— silk, 1751–3.
—— winding frame, 1698–9, 1700.
Douglas's green, 1549.
Doulton ware, 1570–3.
Down, 905.
Dracæna indivisa (fibre), 945.
—— spp. (resin), 1624, 1648.
Drachenblut, 1648–9.
Dracocephalum moldavicum (oil), 1417.
Dragon's-blood, 1624, 1625, 1648, 2025.
Draining sugar, 1857, 1900–1, 1931–5.
Drain-pipes, 1572–3.
Dramming silk, 1753–4.
Draught and air (sulphuric acid), 61, 88.
Drawing cotton, 749.
—— frame for flax, 1249.
—— -in cotton, 779.
—— —— jute, 1185.
—— jute, 1180.
Dressing flax, 1246.
—— leather, tannage of, 1232.
Drew, Heywood, and Barron's flower-still, 1457–8.
Driers (varnish), 2027–8.
Drimia ciliaris (drug), 826.
Drogueries, 790–827.
Dromaius novæ hollandiæ (oil), 1375.
Droseræ (dye), 863.
Drugs, 790–827.
—— aconite, 791.
—— ajowan, 791.
—— aloes, 791–3.
—— ammoniacum, 793.
—— angostura, 793.
—— areca, 793.
—— arnica, 793.
—— asafœtida, 793.
—— atees, 793.
—— bael, 793.
—— barberry, 794.
—— bearberry, 794.
—— belladonna, 794.
—— bibliography, 827.
—— black-roots, 794.
—— boldo, 794.
—— bonduc, 794.
—— broom-tops, 795.
—— buchu, 795.
—— buckthorn, 795.
—— cajuput, 795.
—— calabar bean, 795.
—— calumba, 795–6.
—— camphor, 796.
—— canella, 796.
—— cantharides, 796–7.
—— capsicum, 797.
—— cascarilla, 797–8.
—— cassia, 798.
—— castor, 798.
—— castor-oil, 798.
—— cebadilla, 798.
—— chamomile, 798–9.
—— chaulmugra, 799.
—— china-root, 799.
—— chiretta, 799.
—— cinchona, 799–808.
—— cocculus indicus, 808.
—— colchicum, 808.
—— colocynth, 808–9.
—— copaiba, 809.
—— coptis, 809.
—— costus, 809.
Drugs coto, 809.
—— croton, 809.
—— cubebs, 809.
—— cumin, 809–10.
—— curari, 810.
—— dill, 810.
—— dita, 810.
—— duboisia, 810.
—— elecampane, 810.
—— ergots, 810–1.
—— fern (male), 811.
—— foxglove, 811.
—— galbanum, 811.
—— gelsemium, 811.
—— gentian, 811.
—— ginseng, 811.
—— guaiacum, 811.
—— gulancha, 811.
—— gurjun, 812.
—— hellebore, 812.
—— henbane, 812.
—— Iceland moss, 812.
—— ipecacuanha, 812–4.
—— iridin, 814.
—— Irish moss, 814.
—— jaborandi, 814.
—— jalap, 814–5.
—— Jew's ear, 815.
—— kava-kava, 815.
—— kino, 815.
—— kokum-butter, 815.
—— koso, 815.
—— lactucarium, 815–6.
—— lignum-vitæ, 816.
—— lime juice, 816.
—— liquorice, 816–7.
—— logwood, 817.
—— lopez root, 817.
—— lycopodium, 817.
—— manna, 817–8.
—— matico, 818.
—— mezereon, 818–9.
—— nux vomica, 819.
—— pareira brava, 819.
—— pellitory, 819.
—— pennyroyal, 819.
—— peppermint, 819.
—— Peru balsam, 819.
—— podophyllum, 820.
—— poppy, 820.
—— quassia, 820.
—— quince, 820.
—— rhatany, 820.
—— rhubarb, 820–2.
—— St. Ignatius' beans, 822.
—— sarsaparilla, 822–3.
—— sassafras, 823.
—— sassy, 823.
—— scammony, 823–4.
—— senega, 824–5.
—— senna, 825.
—— snake-roots, 825.
—— squill, 825–6.
—— stavesacre, 826.
—— storax, 826.
—— stramonium, 826.
—— sumbul, 826.
—— tamarinds, 826.
—— taraxacum, 826.
—— valerian, 826.
—— wahoo, 826.
—— wormseed, 827.
Dryandra cordata (oil), 1411–2.
Dry collodion processes, 1537–8.
Drying flax yarn, 1254.
—— indiarubber, 1143.
—— oils (varnish), 2023–4.
—— pottery, 1576–7.
—— rope and twine, 1701–3.
—— sheds for leather, 1232.
—— soap, 1783.
—— spread fabrics, 1148.
—— starch, 1825–6.
—— upper leathers, 1234.
Dryobalanops spp. (camphor), 576–7, (oil) 1397, (resin) 1624.
Duboisia spp. (drug), 810, (oil) 1324.
Dubrul's cigar-scrap machine, 1345.
Duca, 1693.
Duchassaing's process (sugar), 1879.
Duck-grease, 1375.
Düfte, 1523–32.
Dugong (ivory), 1176, (oil) 1365, (skin) 1757.
Dulcite, 1830.
Dummele (resin), 1684.
Dumont filters, 1851.
Duncan & Newlands' alum process of sugar-refining, 330–2, 1927–8.
—— —— —— elution process (sugar-refining), 1933–4.
Dunder (alcohol), 204.
Dünger, 1256.
Dunlop's tape-cutting machine (indiarubber manufactures), 1146.
Duolin, 901.
Dup salai (resin), 1677.
Durieux et Roettger's filter-press, (beet-sugar), 1849.
Durma mats, 919.
Dusting rags, 1491.
Dutchman's laudanum, 1307.
Dyeing and Calico-printing, bibliography, 854.
—— —— —— calico-printing, 835–54.
—— —— —— cotton-dyeing, 828–35.
—— —— —— generalities, 827–8.
—— calf-kid (leather), 1237.
—— carpets, 2105–6.
—— cotton, 827–35.
—— glove-kid (leather), 1239.
—— hair, 1100.
—— hats, 1112, 1120.
—— ostrich plumes, 908.
—— silk, 1754.
Dyers' aquafortis, 1302.
—— composition, 1302.
Dyes for hats, 1113, 1120.
Dye-stuffs, 854–69.
—— alkanet, 855.
—— aloes, 855.
—— annatto, 855.
—— barwood, 855.
—— berberin, 855–6.
—— bibliography, 869.
—— brazil-wood, 856.
—— broom, 856.
—— camwood, 856.
—— cauline, 856.
—— chay, 856.
—— Chinese-green, 856.
—— cochineal, 856–7.
—— ericine, 857.
—— fustic, 857–8.
—— gardine, 858.
—— generalities, 854–5.
—— godari, 858.
—— henna, 858.
—— Indian mulberry, 858.
—— indigo, 858–61.
—— kamala, 861.
—— kermes, 861.
—— lac, 861–2.
—— lan, 862.
—— laureline, 862.
—— litmus, 862.
—— logwood, 862.
—— madder, 862–3.
—— Mexican blue, 863.
—— munjeet, 863–4.
—— nag-kassar, 864.
—— orchella, 864.
—— osage orange, 864.
—— Panama crimson, 864.
—— Persian berries, 864.
—— poppy, 864.
—— puph, 864.
—— quercitron, 864–5.
—— safflower, 865–6.
—— saffron, 866–7.
—— sanders-wood, 867.
—— sapan-wood, 867.
—— tisso, 867.
—— Tokio purple, 867–8.
—— turmeric, 868.
—— walnut, 868.
—— weld, 868.
—— woad, 868–9.
—— yellow berries, 864.
Dyewoods refuse for acetic acid, 15–19.
Dynamite, 901.

EAGLE vitriol, 1297.
—— wood, 1523–4.
Ear-shells, 1517, 1520.
Earthenware, 1558, 1573–82.
—— cement, 627.
Earth-nut, 1357–8.
—— wax, 2046.

East Asian dragon's-blood, 1648.
—— Indian copal, 1641–2.
—— —— dammar, 1644.
—— —— elemi, 1649.
—— —— gum, 1621, 1632.
—— —— kino, 1667–8.
—— —— mastic, 1673.
—— —— sugar-cane, 1860.
Eastern sea-salt industry, 1718.
Eastes' process, defecating cane-juice, 1888.
—— —— sugar-refining, 1929.
Eau de Chypre, 1532.
—— de Cologne, 1532.
—— de Luce, 1532.
—— de millefleurs, 1532.
—— de mousseline, 1532.
—— de Portugal, 1532.
—— de vie de marc, 202.
—— des carmes, 1532.
—— forte, 148–60.
—— régale, 335.
Eaux, 1532.
—— gaseuses, 362–77.
Eboe-tree (oil), 1379.
Ebony, 2015.
Echaltium piscidium (fibre), 982.
Echinus philippinensis (dye), 861.
Echites scholaris (drug), 810.
Economies in glass-manufacture, 1086.
Écorces de chêne, 1987–8.
Écuelles for extracting essential oils, 1457.
Eda (resin), 1648.
Edible banana (fibre), 982.
Edgeworthia Gardneri (fibre), 948.
Edwards' heliotype, 1619–20.
Egg cement, 627.
—— oil, 1365–6.
Eggs, preserving, 1016.
Eglantine extract, 1528.
Egusi-oil, 1395.
Ehrard's biting-in process, 1618.
Eichenrinden, 1987–8.
Eider down, 905.
Eisenhut, 791.
Ejoo fibre, 919.
Elæagia utilis (wax), 2044.
Elæis guineensis (fibre) 948, (nut) 1359, (oil) 1406–8.
—— melanococca (oil), 1385.
Elæocarpus spp. (tannin), 1993.
Elæococca vernicia (oil), 1411–2.
Elæodendron Argan (oil), 1377–8.
—— paniculatum (resin), 1666.
Elæoselinum sp. (resin), 1630.
Elaphrium spp. (resin), 1623.
—— tomentosum (resin), 1683.
Elastic cement, 623.
Elate sylvestris (resin), 1693.
Elder-flower soap, 1791.
—— —— water, 1532.
—— oil, 1420.
Elecampane, 810.
Electrical apparatus, cement for, 623.
Electro-metallurgy, 869–82.
—— batteries, 869–70.
—— bibliography, 881–2.
—— brass-plating, 881.
—— cleansing surfaces, 870–1.
—— conductivity of metals, 869.
—— copper deposits, 876.
—— deposition of metals, 869.
—— dipping, 872.
—— electrotyping type, 877.
—— gilding, 878–80.
—— magneto-electric machines, 870.
—— moulds and moulding, 872–6.
—— nickel-plating, 880–1.
—— plating tanks, 871–2.
—— silvering, 877–8.
—— steel-plating, 881.
Elemi, 1623, 1625, 1649, 1677, (oil) 1420
Elephant grass, 999.
—— ivory, 1173.
—— sugar-cane, 1861.
Elephas spp. (ivory), 1173–5.
Elettaria Cardamomum (spice), 1803–4.
Eleuthera, 797.
Elfenbein-schwarz, 455.
Elk hair, 1094.
Ellebore, 812.
Ellis auxiliary for engines, 607.
Elm (acetic acid) 14, (potash) 255, (timber) 2015.
El mogen (narcotic), 1307.
Elution process (sugar), 1859–60, 1933–4.
Ema fibre, 919.
Embelia Ribes (spice), 1814.
Emblica officinalis (resin), 1693.
Embryopteris glutinifera (resin), 1684.
Emerald, 1042.
—— green, 1549.
Emetic holly, 1308.
Empleurum serrulatum (drug), 795.
Emu-grease, 1375.
Enamelled leather, 1236, 2032.
Enamels, 1085, 2031–2.
Encaustic tiles, 1587–94.
Encens, 1676–7.
Encephalartos spiralis (starch), 1823.
Enemies, coco-nut, 939.
—— coffee, 698–700.
—— cotton, 957.
—— olive, 1400–1.
—— sugar-beets, 1835.
—— sugar-canes, 1868–70.
—— tea, 1997.
—— tobacco, 1330.
Enfleurage of odours, 1456.
Engineers' lute, 629.
English china, 1596–7.
—— rock-salt districts, 1721–3.
Engrais, 1256–77.
Engraving and printing, 1601–20.
—— bibliography, 1620.
—— inks, 1172.
—— on copper, 1613.
—— on steel, 1613–4.
—— on stone, 1614–6.
—— on wood, 1610–3.
—— on zinc, 1616.
—— steel cylinders, 1614.
Enhydra marina (fur), 1032.
Enlarging camera, 1535.
Entada scandens (drug), 795.
Entenfuss, 820.
Enzian, 1809.
Enziangeist, 1809.
Eosine, 683.
Ephedra antisyphilitica (tannin), 1993.
Epicauta spp. (drug), 797.
Épices, 1802–17.
Éponge, 1817–21.
Erd amber, 1628.
Erdnussöl, 1391.
Erdöl, 1433–47.
Erechthites hieracifolia (fibre), 948.
Ergot, 810.
Eria silkworms, 1745–6.
Erica vulgaris (dye), 857.
Ericine, 857.
Eriodendron anfractuosum (oil), 1414, (resin) 1693.
—— spp. (fibre), 948.
Eriolæna Hookeriana (resin), 1668.
Eriophorum comosum (fibre), 948.
Eriostemon squameum (oil), 1432.
Ermine fur, 1030.
Erodium moschatum (musk), 1525.
Eryngium (fibre), 948.
Eryops resin, 1625.
Erythrina indica (resin), 1693, (for shade) 1813, 1815.
—— spp. (resin), 1668, (for shade) 716, 719.
Erythrobenzine, 664.
Erythrophlæum guineense (drug), 823.
Erythroxylon Coca (narcotic), 1307.
—— monogynum (resin), 1684.
Esenbeckia febrifuga (drug), 793.
Eseré-nut, 795.
Esparto, 978–9.
—— beating, 1489.
—— bleaching, 1488–9.
—— boiling, 1486–7.
—— characters and uses, 981.
—— chief localities of production, 980.
—— colouring, 1490–1.
—— commerce and values, 981.
—— cultivation, 979–80.
—— for paper, 1485.
—— picking, 1486.
Esparto sizing, 1489–90.
—— treatment for paper making, 1486–91.
—— washing, 1487–8.
Espinillo (tannin), 1993.
Esprit pyroacétique, 39.
Essence de bigarade, 1425.
—— —— Portugal, 1425.
—— —— roses, 1427–30.
—— of turpentine, 1688–91.
—— varnishes, 2035–6.
Essences, 1528–9.
—— soap, 1792.
Essential oils, distillation, 1457–8.
—— —— expression, 1457.
—— —— extraction, 1456–9.
—— —— —— by maceration, 1458–9.
—— —— —— by solvents, 1456–7.
—— vegetable oils, 1415–33.
Essig, 2038–42.
Essigäther, 39.
Essiggeist, 39.
Essigsäure, 5–39.
Essigsäures natron, 37–8.
Essorage of leather, 1234.
Estimation, ammonia, 247.
—— tin in muriates, 1301.
—— —— in soda stannate, 1303.
Estremadura phosphate, 1261.
Eszterhazy bouquet, 1530.
Ether ice-machines, 673, 1135–7.
—— varnishes, 2037.
Ethyl acetate, 39.
—— aniline, 657.
—— mauvaniline, 668.
—— rosanilines, 667.
Eucalyptose, 1830.
Eucalyptus gigantea (timber), 2021.
—— kino, 1668.
—— oils, 1420–1.
—— spp. (fibre), 948, (resin) 1668, (tannin) 1993, (timber) 2015–6.
—— viminalis (drug), 818.
Eugenia caryophyllata (spice), 1807–8.
—— Pimenta (oil), 1416, (spice) 1814.
—— spp. (tannin), 1993.
—— variabilis (tea), 2011.
Eugénie bouquet, 1530.
Eugeissonia tristis (fibre), 948.
Eumitopius Stelleri (fur), 1032.
Euonymus atropurpureus (drug), 826.
—— europæus (oil), 1388.
—— sp. (timber), 2018.
Eupatorium glutinosum (drug), 818.
Euphorbia spp. (oil), 1414, (resin) 1624, 1626, 1627, 1649, 1665.
Euphorbium, 1624, 1626, 1627, 1649, 1665.
European rock-salt districts, 1719–21.
—— sea-salt industry, 1717.
Euryangium Sumbul (drug), 826.
Eurybia argophylla (musk), 1525.
Euryops multifidus resin, 1674.
Euterpe oleracea [edulis] (oil), 1378, (resin) 1663.
Evans' travelling handler, 1229.
Evaporation beet-juice, 1854–7.
—— cane-juice, 1890–1900.
—— glucose, 1917–8.
—— patents, 1936–7.
—— soda liquors (soda), 298–9.
—— sorghum-juice, 1911–2.
—— syrup (sugar-refining), 1926–7.
Evodia febrifuga (drug), 793.
Evrard's skimmer, 1847.
—— process for purifying oils and fats, 1460.
Ewers, pressing, 1579–80.
Excœcaria sebifera (oil), 1412.
Exhausting tanning materials, 1226.
Exile oil, 1414.
Exogonium Purga (drug), 814–5.
Explosives, 882–903.
—— bibliography, 903.
—— cotton powder or tonite, 897.
—— fulminates, 902–3.
—— guncotton, 896–7.
—— gunpowder, 882–96.
—— nitro-glycerine compounds, 897–902.
—— picrates, 902.
Explosives, Schultz's powder, 897.
Extract (woollen manuf.), 2058–9.
Extracts, 1528–9.
Exudations, how obtained, 803, 817, 1639, 1651, 1653, 1655, 1656, 1658, 1659, 1661, 1662, 1664, 1677, 1684, 1686, 1687–9, 1691, 1692, 1902–3, 2044, 2045, 2046.

FABRICS, preparing water-proofed, for curing, 1149.
—— [greasy], recovery of grease from, 605–6, 1455.
—— spreading and water proofing, 1148.
Fagus, spp. (timber), 2012–3.
—— sylvatica (tar), 1683.
Faham tea-plant, 1528.
Fallows for sugar-cane, 1865–6.
Fan palm, 946.
Fanna skimi (spice), 1802–3.
Färbematerialien, 854–69.
Farben, 1548–52.
Farberei, 827–54.
Farinaux's filter-press (beet-sugar), 1849.
Farn, 811.
Fashook (resin), 1630.
Fasus (resin) 1676.
Fat lute, 629.
Fats and oils, extraction, 605, 1447–59.
—— —— —— tables of actual densities of, 1469–70.
—— bleaching, 1459–62.
—— clarifying, 1459–62.
—— containing glycerides of soluble and insoluble fatty acids, analysis of, 1464–6.
—— correcting rancidity in, 1461.
—— decolorizing, 1461–2.
—— deodorizing, 1461.
—— detection and analysis, 1462–77.
—— estimating organic and mineral impurities in, 1462.
—— —— moisture in, 1462.
—— (vegetable) extraction of, 1451–5
—— for soap-making, 1766–7.
—— neutral, soap from, 1771–4.
—— refining, 1459–62.
—— removal of resinous matters from, 1460.
—— saponification, 579–82, 583–6.
—— vegetable, 1377–1415.
Fatty acids, estimation, 1462–3.
—— —— soap from, 1771.
—— —— table of, 1765.
—— matters, extraction of, 605.
—— oils, mutual detection of, 1469–71.
—— substances, 1360–1484.
Faure's cane defibrator, 1878.
Faux baume de Giléad, 1686–7.
Feathers, 904–9.
—— bibliography, 909.
—— common feathers, 904–5.
—— down, 905.
—— fabrics from, 904.
—— ornamental feathers, 905–8.
—— quills, 908–9.
Fécule, 1821–9.
—— de pomme-de-terre, 1823–6.
Fehling's method of sugar analysis, 1948.
Felis spp. (fur), 1030, 1031, 1033.
—— Uncia (oil), 1376.
Felspar, 1560.
—— carbonate potash from, 260.
Felt hats, 1102–21.
—— indiarubber, 1149.
Fennel-oil, 1421.
Fermentation, acetous (acetic acid), 6–7.
—— alcohol, 194–6.
—— beer, 401–11.
—— beet-juice (alcohol), 210.
—— coffee, 703.
—— in leather-dressing, 1219, 1220 1222, 1223, 1224, 1230, 1232.
—— process of sugar analysis, 1948.
—— tea, 2001.
—— vinegar, 2039.
—— wine, 435–7.
Fern, potash from, 255.

Fern [male] (drug), 811, (oil) 1414.
Feronia elephantum (drug) 793, (oil) 1414, (resin) 1621, 1668, 1692–3.
Feroniagummi, 1692–3.
Ferric chloride, 1298.
—— sulphate, 1298.
Ferricyanide potassium, 267.
Ferridcyankalium, 267–8.
Ferrocyanide potassium, 268.
Ferrocyankalium, 268–73.
Ferrocyankalium, 268–73.
Ferrous chloride, 1298.
Ferula alliacea [Asafœtida] (resin), 1633.
—— Narthex (resin), 1633.
—— spp. (drug), 793, 811, (resin) 1624, 1630, 1650, 1681.
—— Sumbul (drug), 826.
Fesca's céntrifugal, 1825.
Fessous (resin), 1676.
Festuca irritans (fibre), 998.
Fettwaaren, 1360–1484.
Fevillea spp. (oil), 1414.
Fiber zibethicus (fur), 1032, (musk) 1525.
Fibrous substances (from plants), 909–1000.
—— Abroma augusta, 911.
—— Abutilon spp., 911.
—— Acacia leucophlœa, 911.
—— Adansonia digitata, 912.
—— Agave americana, 912–6.
—— —— sisalana, 916–7.
—— —— vivipara, 917.
—— Aloë spp., 917.
—— Ampelodesmos tenax, 917.
—— Ananassa sativa, 917–9.
—— Andromachia igniaria, 919.
—— Andropogon Martini, 919.
—— Anona squamosa, 919.
—— Antiaris saccidora, 919.
—— Apocynum cannabinum, 919.
—— Areca Catechu, 919.
—— Arenga saccharifera, 919.
—— Artocarpus spp., 919.
—— Arundo spp., 919–20.
—— Asclepias spp., 920.
—— Astelia spp., 920.
—— Astrocaryum spp., 920.
—— Attalea funifera, 920.
—— Bambusa, spp., 920–1.
—— Bauhinia spp., 921.
—— Beaumontia grandiflora, 921.
—— Bœhmeria spp., 931–32.
—— Bombax spp., 932.
—— Borassus flabelliformis, 932–3.
—— Bromelia spp., 933.
—— Broussonetia spp., 933.
—— Butea spp., 933.
—— Calotropis spp., 933–4.
—— Camelina sativa, 934.
—— Cannabis sativa, 934–8.
—— Carludovica palmata, 938.
—— Caryota urens, 938.
—— Cavanillesia platanifolia, 938.
—— Celosia cristata, 938.
—— Celtis orientalis, 938.
—— Chamærops spp., 938–9.
—— Chlorogalum pomeridianum, 939.
—— Chorisia speciosa, 939.
—— Cibotium Barometz, 939.
—— Cocos nucifera, 939–40.
—— Copernicia cerifera, 940.
—— Corchorus spp., 940–5.
—— Cordia spp., 945.
—— Cordyline spp., 945–6.
—— Corypha spp., 946.
—— Crotalaria spp., 946–7.
—— Cryptostegia grandiflora, 947.
—— Cyperus spp., 947.
—— Cytisus scoparium, 947.
—— Dæmia extensa, 947.
—— Daphne spp., 947.
—— Debregeasia spp., 947–8.
—— Diplarrhena Morœa, 948.
—— Dolichos spp., 948.
—— Dombeya cannabina, 948.
—— Edgworthia Gardneri, 948.
—— Elæis guineensis, 948.
—— Erechthites hieracifolia, 948.
—— Eriodendron spp., 948.
—— Eriophorum comosum, 948.
—— Eryngium sp., 948.
—— Eucalyptus spp., 948.
—— Eugeissonia tristis, 948.
Fibrous substances, Fitzroya patagonica, 948.
—— Fourcroya longæva, 948.
—— Freycinetia Banksii, 948.
—— Gossypium spp., 948–60.
—— Grewia spp., 960.
—— Guazuma tomentosa, 960.
—— Hardwickia binata, 961.
—— Helianthus spp., 961.
—— Helicteres Isora, 961.
—— Hibiscus spp., 961–2.
—— Holoptelea integrifolia, 962.
—— Holostemma Rheedianum, 962.
—— Humulus Lupulus, 962.
—— Iris pseudacorus, 962.
—— Jubæa spectabilis, 962.
—— Kydia calycina, 962.
—— Lagetta lintearia, 962–3.
—— Laportea pustulata, 963.
—— Lardizabala biternata, 963.
—— Lasiosiphon speciosus, 963.
—— Lavatera spp., 963.
—— Leopoldinia Piassaba, 963.
—— Lepidosperma gladiata, 963.
—— Linum usitatissimum, 964–78.
—— Lygeum Spartum, 978–9.
—— Macrochloa tenacissima, 979–81.
—— Malachra capitata, 981–2.
—— Malva spp., 982.
—— Maranta obliqua, 982.
—— Marsdenia tenacissima, 982.
—— Mauritia flexuosa, 982.
—— Melodinus monogynus, 982.
—— Musa spp., 982–5.
—— Nidularium karatas, 985.
—— Nipa fruticans, 985.
—— Ochroma Lagopus, 986.
—— Ocymum spp., 986.
—— Oenocarpus Bacaba, 986.
—— Orthanthera viminea, 986.
—— Pachyrrhizus angulatus, 986.
—— Pandanus spp., 986.
—— Pederia fœtida, 986.
—— Phœnix dactylifera, 986.
—— Phormium tenax, 986–93.
—— Pimelea spp., 993.
—— Pinus sylvestris, 993.
—— Pipturus spp., 994.
—— Plagianthus spp., 994.
—— Poa spp., 994.
—— Prionium Palmita, 994.
—— Psamma arenaria, 994.
—— Raphia spp., 994.
—— Sabal Palmetto, 994.
—— Saccharum spp., 994–5.
—— Salix spp., 995.
—— Sanseviera spp., 995–6.
—— Scirpus lacustris, 996.
—— Sesbania spp., 996.
—— Sida spp., 996–7.
—— Spartina spp., 997.
—— Spartium junceum, 997.
—— Spathodea Rheedii, 997.
—— Sponia spp., 997.
—— Sterculia spp., 997.
—— Stipa spp., 997–8.
—— Strophantus sp., 998.
—— Thespesia spp., 998.
—— Tilia spp., 998.
—— Tillandsia usneoides, 998.
—— Touchardia latifolia, 998.
—— Triodia irritans, 998.
—— Tritoma spp., 998.
—— Typha spp., 999.
—— Urena spp., 999.
—— Urtica spp., 999.
—— Xerotes spp., 999.
—— Xylopia spp., 999.
—— Yucca spp., 999.
—— Zizania aquatica, 999–1000.
Fichtenharz, 1679.
Fichtentheer, 1683.
Ficus Carica (fruit), 1024–5.
—— cordifolia (rubber), 1672.
—— elastica (rubber), 1656–7.
—— spp. (oxalic acid), 161, (rubber) 1624, 1628, 1652, 1656, 1657, 1658, 1664, 1665, 1668, 1669, 1671, (wax) 2044.
Fig soap, 1776–7.
Fig-tree wax, 2044.
Figs, 1024.
Fiji rubber, 1664.
Filberts, 1358.
Filled soaps, 1785–8.
Filling-machine (matches), 1279.
Film evaporators for cane-juice, 1892.
Filter-presses for lime scums (beet-sugar), 1848–9.
Filters, bag, 651.
—— stoneware, 1573.
Filtration, beet-juice through animal charcoal, 1851–4.
—— cane-juice, 1889–90.
—— glucose, 1916–7.
—— green oils (from coal), 651.
—— oils and fats, 1459.
—— patents, 1937.
—— sugar-refining, 1922–3.
—— tartaric acid, 177–9.
Fine salts, 1732.
Fingerhut, 811.
Fingers of flax, 1243.
Fining vinegar, 2039–40.
Finishing hats, 1116.
—— jute, 1185.
—— machines, 1603.
—— silk hats, 1124.
—— -spirit, 1302.
Fir (acetic acid), 14–5.
—— silver, 2015.
—— white, 2014.
Fire-bricks, 1570.
—— -clay, 639.
—— -proof lute, 629.
—— —— and waterproof lute, 629.
—— —— terra-cotta, 1586–7.
—— testing petroleum, 1479–81.
—— -ware, 1569–70.
Fireweed, 948.
Firmin's process (tartaric acid), 177.
Firniss, 2023–38.
First, second, and third sugars, 1857.
Fischbeine, 524–5.
Fish manures, 1257.
—— oils and fats, 1361–77.
—— preserving, 1016–7.
—— skins, 1757.
Fisher fur, 1030.
Fishery-salt, 1732–3.
Fitch fur, 1030.
Fitting soap, 1780.
Fitzhenry scouring-machine (leather), 1235.
Fitzroya patagonica (fibre), 948.
Fixed oils and fats [vegetable], extraction of, 1451–5.
Flashing-points of oils, 1479–81.
Flax, 964–78.
—— brands, 977–8.
—— breaking machines, 969–73, 1246.
—— characters and uses, 977.
—— commerce and values, 978.
—— cultivation, 965–7.
—— cutter, 1246.
—— drawing, 1249.
—— dressing and sorting, 1246.
—— distribution, 964–5.
—— extraction, 967–75.
—— factories in Great Britain and Ireland, 1255.
—— for paper, 1485.
—— hackling, 1244.
—— (hackled), lengths of, 1246.
—— local modifications, 975–7.
—— longs and shorts, 1244.
—— manufactures, 1240.
—— middles, long middles, &c., 1246.
—— parcels and tipples, 1244.
—— preparing, 1247.
—— reeling, 1253.
—— retting, 967–9.
—— roughing, 1243.
—— roving, 1249–51.
—— scutching, 973–5.
—— seed-oil, 1393–4.
—— spreading, 1247–9.
—— -spinning machines, 1252.
—— -stones, -stricks, -fingers, and -pieces, 1243.
—— weaving, 1254.
—— yarn bundling, 1254.
—— —— drying, 1254.
—— —— table, 1254.
Flesh as manure, 1257.
Fleshing processes, 1224.
Fletcher's aspirators, 131, 134.
Fliesen amber, 1628.
Flint crusher, 1561.
—— furnace, 1560–1.
Floating soaps, 1792.
Floorcloth, 1000.
—— boulinikon, 1015.
—— corticine, 1015.
—— kamptulicon, 1015.
—— linoleum, 1001–15.
—— oilcloth, 1001.
Flowers, maceration of, 1458–9.
—— stills, 1457–8.
—— vases (glass), 1072.
Fluorspar, 147–8.
Fluorescine, 682.
Flussharz, 1640–4.
Flux, black, 279.
Fœniculum officinale (oil), 1421.
Food preservation, 1015–22.
—— —— bibliography, 1022.
—— —— dairy produce, 1016.
—— —— fish, 1016–7.
—— —— fruit, grain, and vegetables, 1017–8.
—— —— meat, 1018–22.
Forbidden fruit, 1026.
Fore-turn rope machine, 1707–9.
Forming fur hats, 1107.
—— hats, 1104.
Fortification, wine, 437.
Fossil ivory, 1175.
Fougère mâle, 811.
Fourcroya cantula (fibre), 917.
—— longæva (fibre), 948.
Fourdinier paper-machine, 1494–9.
Fox fur, 1031.
Foxglove, 811.
Fox Talbot's photo-engraving process, 1618.
Frames, soap, 1781.
Frangipanni satchet, 1531.
Frankfort-black, 454.
Frankincense, 1623, 1637, 1649–50 1676–7, 1684.
Fraser's phormium machine, 989.
Fraxinus chinensis (ink), 1170, (wax) 2044.
—— excelsior (timber), 2012.
—— spp. (drug), 817–8.
Freezing (carbolic acid), 673–4.
—— artificial (ice), 1134–42.
—— bibliography, 1142.
—— by ammonia, 237.
—— cane-juice, 1900.
—— -machines, 1135–42.
—— -mixtures, 1134.
French Morocco (leather), 1236.
—— phosphates, 1262.
—— polish, 2037.
—— sable fur, 1031.
—— sea-salt industry, 1717, 1737.
—— silk, 1744.
Frenela Fontanesii (resin), 1681.
—— spp. (resin), 1682.
Fresh-water pearls, 1517.
Freycinetia Banksii (fibre), 948.
Friars' balsam, 1638.
Friedrichshall bitter water, 364.
Frigate-bird oil, 1375.
Frisbie's feeder for furnaces, 1052.
Fritillaria Meleagris (oxalic acid), 161.
Fruit, 1022–9.
—— almonds, 1022.
—— bananas, 1022–3.
—— bibliography, 1029.
—— citrons, 1023.
—— commerce, 1022.
—— currants, 1023–4
—— dates, 1024.
—— figs, 1024–5.
—— gum, 1645–7.
—— lemons, 1025.
—— limes, 1025.
—— oranges, 1025–7.
—— pineapples, 1027.
—— plums, 1027.
—— preserving, 1017–8
—— raisins, 1027–8.
—— tamarinds, 1028.
Fruits de carvi, 1803.
Fruits, sugar in, 1943.
Fry's process (acetic acid), 19.
Fryer's concretor, 1898–1900.
Fuchsia macrostemma (tannin), 1993.
Fucus crispus (drug), 814.
Fullers' teazle, 2084.
Fulling hats, 1109.
—— stocks (hats), 1109.

Fulling stocks, dyes and stains (hats), 1120.
Fulmar-oil, 1375.
Fulminates, 902.
Fuming sulphuric acid, 51.
Fumitory, potash from, 255.
Fungi on sugar-cane, 1869–70.
Fungus, Siberian or intoxicating, 1324.
Fur, 1029–33.
—— badger, 1030.
—— bear, 1030.
—— beaver, 1030.
—— bibliography, 1033.
—— blowing, 1107.
—— cat, 1030.
—— chinchilla, 1030.
—— collecting, 1029.
—— dressing, 1029.
—— ermine, 1030.
—— fisher, 1030.
—— fitch, 1030.
—— forming, 1107.
—— fox, 1031.
—— hamster, 1031.
—— hare, 1031.
—— kolinski, 1031.
—— lion, 1031.
—— lynx, 1031.
—— marten, 1031.
—— mink, 1031–2.
—— monkey, 1032.
—— musk-rat, 1032.
—— nutria, 1032.
—— opossum, 1032.
—— otter, 1032.
—— otter [sea], 1032.
—— rabbit, 1032.
—— raccoon, 1032.
—— seal, 1032–3.
—— —— oil, 1375.
—— skunk, 1033.
—— squirrel, 1033.
—— tiger, 1033.
—— wolf, 1033.
—— wolverine, 1033.
Furnaces, arsenic, 336–8.
—— bone-black, 453.
—— carbonating (soda), 300–1.
—— dandy, 117–8.
—— for ball soda, 290, 292–4.
—— —— bottle-glass, 1075.
—— —— cane-mills, 1876–7.
—— —— destroying noxious vapours, 1276.
—— —— earthenware glaze, 1580.
—— —— spent tan, 1228.
—— —— vinasses, 258.
—— glass, 1049.
—— nitric acid, 156.
—— salt-cake, 282–5.
Furneval's square-beater (bleaching), 478.
Furs for hats, 1106.
Fusel oil, 212, 1421.
Fussblatt, 820.
Fustic, 857.
Fuzes, 902,

GAD'S cement, 627.
Gadus spp. (oil), 1363–5.
Gaïac, 1651.
Galabrun's frame (candles), 593.
Galactodendron utile (resin), 1665.
Galactose, 1830.
Galam-butter, 1410.
Galam, gomme de, 1631.
Galangal, 1808, (oil) 1421.
Galba-oil, 1379.
Galbanum, 811, 1624, 1626, 1650, (oil) 1421.
Gale-oil, 1421.
Galgant, 1808.
Galingale, 1808.
Galiocerda tigrina (oil), 1367.
Galipea spp. (drug), 793.
Galipot, 1684.
Galläpfel, 1983–4.
Galle d'Alep, 1983–4.
Galleria sp. (resin), 1671.
Gallic acid, 50.
Galline, 682.
Gallussäure, 50–1.
Galls, 1983–4.
Galvanism for defecating cane-juice, 1890.
Gambia kino, 1663.
Gambier, 1984–5.
Gamboge, 1551, 1624, 1626, 1650–1, 2025, (butter), 1388.
Ganda (tar), 1684.
Ganja, 1305–6.
Gantert's washing-machine (bleaching), 507.
Garcinia indica (oil), 1395.
—— pictoria (oil), 1388.
—— spp. (drug), 815, (pigment) 1551, (resin) 1624.
Gardenia florida (tea), 2010.
—— spp. (dye), 858, (resin) 1624, 1648.
Gardine, 858.
Gare for glove-kid (leather), 1238.
Garlic-oil, 1421.
Garric and Terson's fleshing-machine, 1224.
Garruga pinnata (lac), 1668, (gum) 1693.
Gas (coal), 1033–40.
—— bibliography, 1040.
—— character of crude gas, 1035.
—— distillation of coal, 1033–4.
—— purification, 1035–40.
—— sulphur from, 241.
Gas-furnace for glass, 1053.
—— for sheet- and crown-glass, 1059.
Gas green, 669.
Gashaltige wasser, 362–77.
Gas-liquor, ammonia from, 235.
—— concentration of, 241.
Gas-tar, distillation, 42–3.
Gases, direction of (sulphuric acid), 65, 90.
—— examining (sulphuric acid), 70.
Gasing cotton, 765.
Gasolene, 1446, 2026.
Gata-oil, 1375.
Gaultheria procumbens (tea), 2011.
—— spp. (oil), 1431–2.
Gaup, 1684.
Gayac beans, 1528.
Gay-Lussac's hydrometer, 215.
—— tower, 72.
Gazella Dorcas (musk), 1525.
Gazelle musk, 1525.
Geel bout wood, 2022.
Geigenharz, 1680–1.
Geisler's alcoholometer, 217.
Gekar, 1676–7.
Gelatine, 1304.
—— emulsion, 1538–9.
—— from bones, 522–4.
Gelbes sandelholz, 1527–8.
Gelsemium, 811.
—— sempervirens (drug), 811.
Gemeiner terpentin, 1687–91.
Gemeines harz, 1680–1.
Gemmage of the pine, 1687–9.
Gemme, 1688.
Gems, 1040–3.
—— artificial, 1040–1.
—— bibliography, 1043.
—— diamond, 1041–2.
—— emerald, 1042.
—— lapis lazuli, 1042.
—— opal, 1042–3.
—— ruby, 1043.
—— sapphire, 1043.
—— topaz, 1043.
—— turquoise, 1043.
Genet, 1524.
Geneva, 222.
Genièvre, 222–3.
Genista scoparia (dye), 856, (fibre) 947.
Gentian, 811, 1805, 1809.
Gentiana Chirayita (spice), 1805.
—— lutea (drug), 811.
—— spp. (spice), 1809.
Geoffroya inermis (dye), 855–6.
Geranium-oil, 1421, 1429.
Geranosine, 662.
Gerbersumach, 1988–92.
Gerbstoffe, 1977–94.
German phosphates, 1263.
—— silver, 323.
—— vinegar process, 7.
Gerstenhoefer's kiln (sulphuric acid), 84.
Geum urbanum (drug), 793, (oil) 1417.
Gewürznelken, 1807–8.
Ghee, 1375.
Ghyul-suyu (oil), 1429.
Giaggiolo, 1526–7.
Giant powder, 901.
Gibbons' phormium machine, 989.
Gibbsite, 332.
Giboia-grease, 1375.
Gigartina, spp. (drug), 814.
Gilding, 878.
Gilead, balm of, 1623, 1636.
Gill spinning frame, 1698.
Gill's rolling machine, 1603.
Gin, 222.
Ging (gum), 1621, 1651.
Gingelly-oil, 1388–90.
Gingembre, 1809–10.
Ginger, 1809–10.
—— beer, 423.
—— grass-oil, 1422, 1429.
—— oil, 1421.
Gingko-nut, 1357.
Ginseng, 811.
Girardinia heterophylla (fibre), 999.
Girofles, 1807–8.
Glacial acetic acid, 21.
Glaise, 635–40.
Glaphyria nitida (tea), 2010.
Glass, 1043–87.
—— and porcelain cement, 627.
—— and wood cement, 627.
—— annealing-ovens, 1055.
—— bibliography, 1087.
—— blowers' tools and seats, 1069.
—— blowing (sheet), 1066.
—— —— (lead), 1069.
—— Bohemian, 1067.
—— bottle, 1075–8.
—— buttons, 559.
—— cane, 1072.
—— case-hardened, 1079.
—— casting-house, 1059.
—— chemistry and physics of, 1043–6.
—— coloured, 1083–4.
—— crown, 1057.
—— —— manufacture, 1063.
—— crucibles, 1046–9.
—— cutting, 1074.
—— cylinders, moulding, 1066.
—— devitrification, 1045–6.
—— economies in manufacture, 1086–7.
—— enamels, 1085.
—— flint- or lead-, and ornamental, 1067–75.
—— flux, 627.
—— forming materials for pottery, 1560.
—— furnaces, 1049–57.
—— grinding, smoothing, and polishing plate-, 1061–2.
—— Hartley's rolled plate, 1061.
—— jugs, 1071.
—— kilns for burning-in stains, 1086.
—— lamp-worked, 1073.
—— lead, 1067.
—— lute, 630.
—— mosaic, 1084–6.
—— opaque, 1083.
—— optical, 1082–3.
—— ornamental, 1067.
—— painted, 1084.
—— paints, 1085.
—— paving-blocks, 1087.
—— plate-, crown-, and sheet-, 1057–67.
—— pressed, 1078–9.
—— raw materials, 1046.
—— retorts (hydrochloric acid), 105–6.
—— —— (sulphuric acid), 96.
—— roughening, 1074.
—— shades, 1067.
—— sheet, 1057.
—— —— manufacture, 1063.
—— —— spreading and annealing kiln, 1066.
—— soluble, 277–8.
—— spun, 1073.
—— stained, 1084.
—— stains, 1085.
—— thallium, 1082.
Glass tiles, 1087.
—— toughened, 1079–82.
—— tubes, 1072.
—— unbreakable, 1079.
Glauber's salts, 317–8.
Glaucium luteum (oil), 1409–10.
Glaze for Sevres, 1595.
Glazes, 1598–9.
Glazing earthenware, 1580–1.
—— paper, 1503.
Globiocephalus spp (oil), 1361.
Glost-oven, 1563.
Glove-kid, 1237.
—— —— dyeing, 1239.
Glover tower (sulphuric acid), 57, 77.
Glucose, 1830, 1914–21.
—— analysis, 1963–5.
—— boiling, 1915–6.
—— capillair-syrup and -sugar, 1920.
—— definition, 1831.
—— determination, 1944–6.
—— evaporation and refining, 1917–8.
—— formation, 1914–5.
—— granulated starch-sugar, 1920.
—— manufacture, 1915–20.
—— neutralization and filtration, 1916–7.
—— other methods of manufacture, 1918–20.
—— packing, 1917–8.
—— patents, 1938–40.
—— principles of manufacture, 1915.
—— uses, 1921.
Glue, 620, 1304.
Glutton fur, 1033.
Glycerine, 1798–1802.
—— cement, 627.
—— estimation, 1466.
—— in water, table, 1801.
—— soaps, 1789, 1792.
—— solidified, 1792.
Glycine Soja (oil), 1378, (spice) 1814.
Glycyrrhiza spp. (drug), 816–7.
Goat-hair, 1095.
—— —— common, 1098.
—— skins, 1757–8.
Godari, 858.
Gold amalgam, 333.
—— assay, 353.
—— detection, 348.
Golden syrup, definition, 1831.
Gold-ink, 1172.
—— -of pleasure-oil, 1390.
Gomme ammoniaque, 1630.
—— arabique, 1630–3.
—— d'acajou, 1638.
—— d'Alsace, 1645–7.
—— de coco, 1639.
—— du pays, 1638–9.
—— friable, 1631.
—— gutte, 1551, 1650–1.
Gommeuses et résineuses, matières, 1620–95.
Gommline, 1645–7.
Googul, 1636.
Goolabi pani, 1428.
Gooler, 1671.
Goolwail, 811.
Goor, 1904–7.
Goose-grease, 1376.
Gordonia floribunda (resin), 1668.
Gossage's aspirator, 130.
Gossypium spp. (cotton manufactures), 729–90, (fibre) 948–60, (oil) 1385–6.
Goudron végétal, 1683.
Goulard's extract, 1300.
Gould beater, 1491.
Gourd-oil, 1395.
Gradishaus, 1726–7.
Graduation system of making white salt, 1726–7.
Grain, alcohol from, 206.
—— composition, 207.
—— d'ambrette, 1524–6.
—— drying (alcohol), 207.
—— germination (alcohol), 207.
—— preserving, 1017–8.
—— steeping (alcohol), 207.
Graining hard soap, 1779.
—— hides, 1233.

Graining sugar, 1893–5.
Graisse de porc, 1366–7.
—— de roussette edule, 1375.
—— d'os, 1361.
Grampus-oil, 1369.
Granulation, cane-sugar, 1890–1900.
—— (gunpowder), 893.
Grapes, 1027.
—— potash from, 255.
—— skins, tartaric acid from, 182.
—— stone-oil, 1390–1.
Graphite, 1087–93.
Grass hemp, 916.
Grass-tree resin, 1693.
Grating-machines (starch), 1824.
—— sugar-beets, 1837–8.
Gravure 1601–20
Grawatha (fibre), 933.
Grease bleaching, 1459–62.
—— clarifying, 1459–62.
—— correcting rancidity in, 1461.
—— decolorizing, 1461–2.
—— deodorizing, 1161.
—— refining, 1459–62.
—— removal of lime from, 1460.
—— —— of resinous matters from, 1460.
—— [waste] recovery, 605–6, 1455–6.
Greasy fabrics, recovery of grease from, 605–6, 1455.
—— liquids, recovery of grease from, 1455–6.
Green, imperial, 31.
—— mitis, 31.
—— mountain, 31.
—— pigments, 1548–9.
—— snail, 1517.
—— vitriol, 1297.
Greenheart starch, 1823, (timber) 2015.
Greens from coal-tar, 668.
Green-soiling sugar-cane, 1865–6.
Greig's machine (fibres), 925.
Grevillea robusta (resin), 1693.
Grewia spp. (fibre), 960.
Grey-mottled soap, 1787–8.
Grieswurzel, 819.
Griffith's white, 1551.
Grinders' cement, 623.
Grinding and mixing rubber, 1149.
—— mineral phosphates, 1268.
—— plate-glass, 1061.
—— tanning materials, 1226.
Grislea tomentosa (dye), 858, (resin) 1693.
Ground-nut, 1357–8, (oil) 1391.
—— shellac, 1693.
Grünspan, 30–1.
Guacharo-oil, 1376.
Guaiacum, 811, 1623, 1624, 1625, 1651.
—— officinale (drug), 811, (timber) 2016–7.
—— spp. (drug), 816.
Guajaharz, 1651.
Guanaco, 1093.
Guano, assay, 358.
—— oxalic acid from, 161–3.
Guanos, 1258.
—— phosphatic, 1265.
Guapeba vermelha (resin), 1694.
Guaracua (resin), 1694.
Guard's bouquet, 1530.
Guarea trichilioides (musk), 1525.
Guariba (grease), 1376, (resin) 1693.
Guayaquil rubber, 1659–61.
Guaza (narcotic), 1306.
Guazuma tomentosa (fibre), 960.
Gubbio ware, 1599.
Guggur (resin), 1636.
Guiana arrowroot, 1823.
Guibourtia copallifera (resin), 1642.
Guignet's green, 1549.
Guilandina Bonducella (drug), 794.
—— Moringa (oil), 1378–9.
Guilandine, 794.
Guillotines, 1603–4.
Guinea pepper, 1803.
Guizotia oleifera (oil), 1396.
Gulancha, 811.
Gulo luscus (fur), 1033.
Gum mucilage, 624.
Gums, composition origin, &c., 1620–1.
Gummi-arten, 1620–95.
Gummigutt, 1551, 1650–1.
Gummy substances, 1620–95.
Gum-resins, 1620–95.
Gum-trees (timber), 2015, 2016.
Guncotton, 896–7.
Gunjah (narcotic), 1306.
Gun-metal, 323.
Gunpowder, 882–96.
—— assay, 359.
—— breaking down, 890–1.
—— charcoal, 882–4.
—— —— grinding, 887.
—— compressed, 894–5.
—— density, 895–6.
—— explosion and prevention, 890.
—— granulating, 893–4.
—— mixing the ingredients, 886–90.
—— pressing, 890–3.
—— saltpetre refining, 884.
—— stoving, 895.
—— sulphur refining, 884–6.
Gurjun, 812, 1624, 1640, 1651–2.
Guru-nut, 1358–9.
Gutta (Malay rubbers), 1652–4, 1656, 1658.
Guttapercha, 1162–4, 1627, 1652–4.
—— manufactures, 1162–4.
—— vulcanized, 1163.
Guttashea, 1410, 1654.
Gutti, 1551, 1650–1.
Gymnema lactiferum (resin), 1665.
Gymnemia tingens (dye), 858.
Gynerium argenteum (fibre), 920.
Gynocardia odorata (drug), 799.
—— spp. (oil), 1382.
Gyrocarpus Jacquinii (resin), 1694.

HAARI tapan (resin), 1639.
Habighadi (resin), 1674.
Hacking's folding-machine (bleaching), 502.
Hackling flax, 1244.
—— machines for flax, 1244.
Hackmatack wood, 2016.
Haddock-oil, 1364.
Hæmatoxylon Campechianum (drug), 817, (dye) 862.
Hagenia abyssinica (drug), 815.
Hair, 1093–9.
—— alpaca, 1093–4.
—— bibliography, 1099.
—— bison, 1094.
—— camel, 1094–5.
—— cattle, 1095.
—— cloth, 1101.
—— curling, 1100.
—— dyeing, 1100.
—— goat, 1095–8.
—— horse, 1098–9.
—— human, 1099.
—— manufactures, 1100–2.
—— pig, 1099.
—— yak, 1099.
Hake-oil, 1364.
Half-blocking silk hats, 1126.
Halicore australis (ivory), 1176.
—— spp. (oil), 1365.
Halimocnemum sp. (soda), 280.
Haliotis spp. (pearl), 1517, 1520.
Halliday's apparatus (acetic acid), 15.
Hallo, 1307.
Halocnemum capsicum (soda), 280.
Hamster fur, 1031.
Hancornia speciosa (resin), 1627, 1664.
Handler, Evans' travelling, 1229.
—— liquors, 1230.
Handles on pottery 1577.
Hand-made cordage, 1696–7.
—— —— lace, 1200.
—— —— paper, 1494.
Hanföl, 1391.
Hansen's writing ball, 1608.
Hard soap, 1777–9.
Hardening hats, 1105.
Hardening-on kiln, 1568.
Hardwickia binata (fibre), 961.
—— pinnata (resin), 1640, 1654.
Hare fur, 1031.
Hargreaves and Robinson's furnace (soda), 287.
"Harp" oil, 1370.
Harpuis-bosch (resin). 1674.
Hartley's rolled plate-glass, 1061.
Harz-arten, 1620–95.
Hashab (resin), 1631.
Hashabi el Jesire (resin), 1631–2.
Hashish (narcotic), 1305, 1307.
Hat blocking, 1114.
—— body-making, 1121.
—— brim beater, 1118.
—— dyeing, 1112, 1120.
—— dyes, 1113, 1120.
—— finishing, 1116, 1124.
—— forming, 1104.
—— fulling, 1109.
—— hardening, 1105.
—— napping, 1120.
—— planking, 1108.
—— pressing, 1115.
—— roughening, 1120.
—— shaping, 1117, 1126.
—— stains, 1113.
—— stiffening, 1110.
—— stoving, 1115.
—— trimming, 1117–27.
—— twisting, 1109.
—— veluring, 1119.
Hats, 1102–27.
—— crown-sewing, 1126.
—— half-blocking, 1126.
—— silk, 1121.
Hatters' cloths, 1127.
—— proofs, 1127.
—— tools, 1121–5.
Hatting furs, 1106.
Häute, 1757–61.
Haute du fleuve, gomme du, 1631.
Hawes' soap boiler, 1772–3.
Hawthorn (acetic acid), 14.
Hazel nut, 1358, (oil) 1391.
Head-matter, 1371–2.
Heat for concentrating cane-juice, 1890–1900.
—— defecating cane-juice, 1884–6.
Heating values of oils, 1478–9.
Hectograph, 1610.
Hedeoma pulegioides (drug), 819.
Hedera helix (resin), 1624.
Hedwigia balsamifera (oil), 1432, (resin) 1623.
Hedyotis umbellata (dye), 856.
Heilmann comber (cotton manuf.), 747.
Helianthus annuus (fibre), 961, (oil) 1411.
—— tuberosus (fibre), 961.
Helicteres Isora (fibre), 961.
Heliopeltis theivora (cinchona), 807.
Heliothis armigera (bell-worm), 957.
Heliotrope extract, 1528.
—— satchet, 1531.
Heliotype, Edwards', 1619–20.
Hellebore, 812.
Helleborus spp. (drug), 812.
Hemidesmus indicus (drug), 823.
Hemileia Vastatrix (coffee), 698.
Hemlock-extract, 1226, 1985.
Hemlock spruce, 1686.
Hemp, 934–8.
—— as a narcotic, 1305.
—— characters and uses, 936–7.
—— cultivation, 934–5.
—— Deckanee, 961.
—— extraction of the fibre, 935–6.
—— for paper, 1485.
—— Manilla, 983.
—— New Zealand, 986.
—— production and commerce, 937–8.
—— Queensland, 996.
Hempseed-oil, 1391, 2024.
Henbane, 812, (oil) 1414.
Henderson's hair loom, 1102.
—— vertical paraffin retort, 1511–2.
Henequen, 916.
Henna, 858.
Henri-Deux ware, 1598.
Hensler's cement, 627.
Heritiera littoralis (resin), 1694.
—— spp. (oil), 1414.
Herring-oil, 1366.
Herschel's cyanotype, 1617.
Hesperis matronalis (oil), 1414.
Hessian crucible, 1558.
Heteropogon insignis (fibre), 919.
Heudoletia africana (resin), 1636–7.
Hevea brasiliensis (oil), 1411.
—— spp. (rubber), 1627, 1661–4.
Hexenmehl, 817.
Hibiscus spp. (fibre), 961–2, (oil) 1397, (musk) 1525.
Hickory-nut, 1358, (oil) 1391–2, (timber) 2015–6.
Hides, 1757–61.
—— anatomical structure, 1213.
—— breaking-over, 1224.
—— chemical composition, 1217.
—— common, tannage of, 1232.
—— customary division of, 1225–6.
—— for sole-leather, 1218.
—— graining, 1233.
—— limeing, 1220.
—— preparation for tanning, 1219.
—— shaved, tannage of, 1232.
—— shaving knife, 1233.
—— soaking, 1219.
—— splitting, 1233.
—— stocks for, 1220.
—— sweating, 1222.
—— tumbler for, 1232.
—— unhairing, 1220.
Hing (resin), 1633.
Hippomane Mancinella (resin), 1665.
Hippopotamus amphibius (ivory), 1175, (grease) 1376.
Hira-bôl (resin), 1674–5.
Hira-bing (resin), 1634.
Hirneola spp. (drug), 815.
Hiusache (tannin), 1993.
Hives for bees, 1129.
Hoastorsk (oil), 1370–1.
Hodthai (resin), 1637, 1674.
Hofmann's green, 669.
—— naphthalene red, 681.
—— process (soda), 313.
Hog gums, 1654, 1686.
—— resin, 1624.
—— tragacanth, 1686.
Holcus saccharatus (sugar), 1861.
Holden's ice-machine, 1139.
Holigarna longifolia (resin), 1692.
Holing sugar-cane estates, 1867.
Hollands, 223.
Holly, emetic, 1308.
Holmes' paint-mill, 1563–4.
Holoptelea integrifolia (fibre), 962.
Holostemma Rheedianum (fibre), 962.
Holy Basil bouquet, 1530.
Holzsäure, 7–21.
Holztheer, 1683.
Honey, 1127.
—— soap, 1789, 1792.
Honeysuckle extract, 1528.
Hood oil, 1370.
Hooshe (timber), 2016.
Hoo-sheet (resin), 1677.
Hopea spp. (oil), 1413, (resin) 1624, 1645.
Hops, 1130, (fibre) 962, (oil) 1422.
—— substitutes for, 1131.
Horehound [black stinking] oil, 1414.
Horia maculata (drug), 797.
Horn, 1132.
Horner flax-hackling machine, 1244.
Horograph, 1609.
Horse-chestnut (acetic acid), 14, (nut) 1353, (oil) 1392, (starch) 1823.
Horse-grease, 1366.
—— hair, 1098.
—— —— vegetable, 938.
—— hides, 1758.
Hosiery, 1186–1200.
—— brushing machine, 1197–8.
—— calendering press, 1197–8.
—— factories, 1199.
Hotai (resin), 1637, 1674.
Houlican-oil, 1366.
Household soaps, 1789.
Hovenia extract, 1528.
Howard's fittings for defecating cane-juice, 1887.
—— splint-cutting machine, 1277.
Howland Island guano, 1265.
Huanaco, 1093.
Huck's sieve (starch), 1824.
Huiles, 1360–1484.
—— blanche de thym, 1431.
—— d'amandes, 1377.
—— d'arachide, 1391.
—— d'argan, 1377–8.
—— de baleine, 1374–5.
—— de belouga, 1369.

Huile de ben, 1378–9.
—— de cade, 1684.
—— de cameline, 1390.
—— de carapa, 1386.
—— de castanheiro, 1379–80.
—— de castor, 1380–2.
—— de châtaignes, 1379–80.
—— de chanvre, 1391.
—— de chènevis, 1391.
—— de coco, 1383–4.
—— de colza, 1384–5.
—— de coton, 1385–6.
—— de croton, 1386–7.
—— de faine, 1378.
—— de fécule, 1392.
—— de foie de morue, 1363–5.
—— de graines de tilly, 1386–7.
—— —— des Moluques, 1386–7.
—— de hanneton, 1375.
—— de jubarte, 1374–5.
—— de juvias, 1379–80.
—— de lamantin, 1367–8.
—— de lentisque, 1409.
—— de lin, 1393–4.
—— de louar, 1369–70.
—— de madool, 1395.
—— de marmotte, 1409.
—— de marron d'Inde, 1392.
—— de marsouin, 1369.
—— de médicinier, 1410.
—— de morse, 1374.
—— de moutarde, 1396.
—— de noisettes, 1391.
—— de noix, 1413.
—— —— de Bancoul, 1392–3.
—— de nordcaper, 1374–5.
—— de Palma-Christi, 1380–2.
—— de palme, 1406–8.
—— de pavot, 1409.
—— de pepins de raisins, 1390–1.
—— de petits pignons d'Inde, 1386–7.
—— de phoque, 1370.
—— de pieds de bœuf, 1368.
—— de pignon d'Inde, 1410.
—— de pistache de terre, 1391.
—— de requin, 1370–1.
—— de ricin, 1380–2.
—— de rorqual, 1374–5.
—— de sardine, 1369–70.
—— de sésame, 1389–90.
—— de tallicoona, 1395–6.
—— de thon, 1373–4.
—— de touloucoona, 1395–6.
—— d'œillette, 1409.
—— d'œufs, 1365–6.
—— d'olives, 1397–1406.
—— rouge de thym, 1431.
Human hair, 1099.
Humirium spp. (resin), 1623.
Humulus Lupulus (fibre), 962, (hops) 1130–1, (oil) 1422.
Hungarian balsam, 1691.
Hungary water, 1532.
Hura crepitans (oil), 1414.
Hurdle for glove-kid (leather), 1239.
Huxham & Brown's tan-furnace, 1228.
Hwangkuyn (oil), 1376.
Hyawa gum, 1649.
Hydnocarpus odorata (oil), 1382.
Hydrargillite, 332.
Hydrastis canadensis (dye), 856.
Hydrated soaps, 1777.
Hydrate potassium, 251.
—— sodium, 305.
Hydraulic limestones, 619.
Hydrochloric acid, 101–47.
—— —— commerce and values, 147.
—— —— composition, 102–4.
—— —— condensers, 108–17.
—— —— estimation, 146–7.
—— —— in nature, 101.
—— —— manufacture, 104–18.
—— —— pans, 106–8.
—— —— prevention of nuisance, 118–46.
—— —— properties, 101–4.
—— —— purification, 147.
—— —— roasters, 108.
—— —— specific gravity, 3.
Hydro-extractors, 495–6, 1825, 1839, 1901, 1934–5, 1937–8.
Hydrofluoric acid, 147.
Hydrometers, 2, 1768.
Hylesinus oleiperda (oil), 1401.
Hymenæa Courbaril (tannin), 1982, (timber) 2017.
—— spp. (resin), 1623, 1641, 1666.
Hyoscyamus niger (drug), 791, 812, (oil) 1414.
—— spp. (drug), 812.
Hyperanthera Moringa (oil), 1378–9.
Hyphæne crinita (nut), 1357.
Hyposulphite alumina, 1296.
—— iron, 1300.
—— sodium, 314, 1300.
Hyssop-oil, 1422.
Hyssopus officinalis (oil), 1422.

IBOTA wax, 2045.
Icaco oil, 1414.
Ice, 1133–42.
—— artificial, 1134.
—— bibliography, 1142.
—— -making machines, 1135–42.
Iceland moss, 812.
Icerya sacchari (cane disease), 1868–9.
Ichneumonidæ for destroying cane pests, 1869.
Icica spp. (resin), 1623, 1649, 1683.
Identification of oils in mixtures, 1467–77.
Idris-yaghi (oil), 1429.
Iguana-grease, 1376.
Ilang-ilang bouquet, 1530.
—— extract, 1528.
—— oil, 1422.
Ilex vomitoria (narcotic), 1308, (tea) 2011.
—— spp. (tea), 2011.
Illicium anisatum 335, (oil) 1414, 1417.
—— spp. (spice), 1802–3.
Illipi-butter, 1392.
Illuminating values of lights, 1544–7.
—— —— of oils, 1477–8, 1547.
Illuminators, relative cost of, 1547.
Imbibition processes for sugar-cane, 1879.
Imbricaria coriacea (resin), 1665.
Imitation gems, 1075.
—— wines, 443.
Impatiens spp. (oil), 1414.
Imperatoria Ostruthium (aconite), 791.
Imperial green, 31.
Impervious cement, 624.
Impression, 827–54.
Imprimerie, 1601–20.
Incense powder, 1529.
—— wood, 1649.
Incenses, 1529–30.
Incorporating mill (gunpowder), 888.
Indian aconite, 791.
—— butter-tree, 1408.
—— bdellium, 1636.
—— elemi, 1649.
—— (East) gum, 1632.
—— gut, 938.
—— inks, 1169.
—— melissa oil, 1423.
—— mulberry (fibre), 858.
—— nettle-tree, 938.
—— olibanum, 1677.
—— pastilles, 1530.
—— red, 1550.
—— sarsaparilla, 823.
—— silk, 1744–7.
—— [East] sugar-canes, 1860.
—— [West] sugar-canes, 1861–2.
—— tobacco, 1336–7.
—— tragacanth, 1621, 1685.
—— varnish, 1692.
—— white wax, 2045.
Indianite cement, 624.
Indiarubber, 1142–64, 1627–8, 1654–66.
—— block, 1145.
—— calendering, 1149–50.
—— cement, 624.
—— Chatterton's compound, 1164.
—— compounds, reworking, 1161.
—— cured goods, testing, 1158.
—— curing or vulcanizing, 1154–8.
—— curing-presses, 1156–7.
—— dissolving rubber, 1147–8.
—— drying, 1143.
—— —— spread fabrics, 1148.
Indiarubber felt, 1149.
—— for dental purposes, 1154.
—— goods, pigments for, 1159.
—— grinding and mixing, 1149.
—— lapping-machine, 1152.
—— manufactures, 1142–64.
—— —— bibliography, 1164.
—— —— guttapercha, 1162–3.
—— —— insulating telegraph-wires, 1151–4.
—— —— joining rubber textures, 1158.
—— —— preparing fabrics for curing, 1149.
—— —— testing cured goods, 1158–9.
—— —— varnishing rubber textures, 1158.
—— —— vulcanized guttapercha, 1163–4.
—— masticating, 1144–5.
—— miscellaneous applications, 1154.
—— moulding, 1160–1.
—— paints or varnishes, 1158.
—— pigments, 1159–60.
—— sheet, 1145–6.
—— —— calendering, 1149.
—— —— testing, 1153.
—— spreading and waterproofing fabrics, 1148.
—— substitutes, 1161–2.
—— tape, 1146.
—— textures, joining, 1158.
—— —— varnishing, 1158.
—— thread, 1146–7.
—— valve-cutting, 1150–1.
—— vulcanizing, 1154.
—— washing and drying, 1143–4.
Indigo (dye), 858, (for green-soiling) 1866.
Indigofera spp. (dye), 858–61.
Industrie lainière, 2047–112.
—— sétifère, 1748–56.
—— toilière, linière, 1240–55.
Inga dulcis (resin), 1668.
—— Feuillei (tannin), 1993.
—— xylocarpa (timber), 2020.
Ingnatiana philippinica (drug), 822.
Ingwer, 1809–10.
Ingwerbier, 423–4.
Injector-kier (bleaching), 486.
Injurious insects, 698–700, 803, 807, 939, 957, 1330, 1400–1, 1835, 1868–70, 1997.
Ink, 1165–72.
—— bibliography, 1172.
—— black writing, 1165–6.
—— coloured writing, 1167–8.
—— copying, 1166–7.
—— engraving, 1172.
—— Indian, 1169–70.
—— invisible, 1168.
—— marking, 1168–9.
—— miscellaneous, 1172.
—— printing, 1170–2.
Inlaid tiles, 1587–94.
Inocarpus edulis (nut), 1353.
Inosite, 1830.
Insect oils and fats, 1361–77.
Instantaneous shutters (photography), 1535.
Insulating materials, 1153.
—— telegraph-wires, 1151.
International bouquet, 1530.
Intoxicating fungus, 1324.
—— long pepper, 1305.
Inula Helenium (drug), 810.
Inversion of sugar in cane-juice, 1871–2.
—— process of sugar analysis, 1948–51.
Invert sugar, 1830–1.
—— —— patents, 1938–40.
Invisible inks, 1168.
Iodide potassium, 273.
—— sodium, 314.
Iodina rhombifolia (tannin), 1988.
Ionidium Ipecacuanba (drug), 814.
Ipecacuanha, 812.
Ipomæa bona nox (resin), 1659, 1660.
—— purgans (resin), 1624.
—— spp. (drug), 814–5.
Iridin, 814.
Iridio-platinum, 324.
Iris florentina (oxalic acid), 161.
—— pseudacorus (fibre), 962.
—— spp. (perfume), 1526-7.
Irish moss, 814.
Iron acetates, 31, 1299.
—— alum, 1298.
—— amalgam, 334.
—— assay, 354.
—— detection, 348.
—— hyposulphite, 1300.
—— liquor, 31–2, 1299.
—— lute, 630.
—— mordants, 1297.
—— muriates, 1298.
—— nitrates, 1298.
—— persulphate, 1298.
—— pots and pans, cement for, 627.
—— pyrolignite, 1299.
—— pyrophosphate, 1300.
—— -wire brushes, 553.
Ironbark, 2016.
Ironwood, 2020.
—— Cape, 2016.
Irvingia Barteri (oil), 1387.
Isatis spp. (dye), 858–61.
—— tinctoria (dye), 868–9.
Isodulcite, 1830.
Isonandra spp. (rubber), 1627, 1652–4.
Isopurpurate ammonia, 680.
—— aniline, 680.
—— potash, 680.
Isopurpurine, 684.
Italian silk, 1743–4.
Iturite (fibre), 982.
Iva-oil, 1422.
Ivory, 1172–6.
—— bibliography, 1176.
—— black, 455.
—— cement for, 624.
—— dugong, 1176.
—— elephant, 1173–5.
—— hippopotamus, 1175.
—— mammoth, 1175.
—— narwhal, 1175.
—— vegetable, 1357.
—— walrus, 1175.
Ixtle (fibre), 985.

JABORANDI, 814.
Jack-tree (as shade), 1812, 1815, (timber) 2016.
Jackass copal, 1641.
Jackson's scouring-machine (leather), 1235.
—— tea-rolling machine, 1999.
Jaggery (beverage), 425–6.
Jalap (drug), 814, (resin) 1624.
Jamaica nutmeg, 1812.
—— pepper, 1814.
Jandul (resin), 1676.
Janipha spp. (starch), 1828.
Japan wax, 2045.
Japanese aconite, 791.
—— galls, 1984.
—— paste, 622.
—— silk, 1744.
—— varnish, 1692.
Japanned leather, 1236, 2032.
Japans, 2031–2.
—— black, 2035.
Jaqua (resin), 1694.
Jarrah wood, 2016.
Jars, stoneware, 1573.
Jasmine-oil, 1422.
Jasminum odoratissimum (oil), 1422.
—— Sambac (tea), 2010.
Jaspar ware, 1598.
Jateorhiza Columbo (dye), 856.
—— palmata (drug), 795–6.
Jatropha Curcas (oil), 1359, (resin) 1694, (for shade) 1815.
—— glauca (oil), 1414.
—— moluccanum (nut), 1352.
—— montana (oil), 1387.
—— spp. (starch), 1828.
Java-almond-oil, 1392.
—— cardamoms, 1804.
—— frankincense, 1637.
—— rubber, 1628, 1656–7.
Jedda gum, 1633.
Jeffersonia diphylla (dye), 856.
Jejomadon (oil), 1377.
Jernang (resin), 1648.

Jetee (fibre), 982.
Jew's-ear, 816.
Jewels, imitation, 1075.
Jewellers' cement, 624.
Jhuri (resin), 1672.
Jigger for pottery, 1578–9.
Jiggers (leather), 1236.
Jockey Club bouquet, 1530.
Johnson, Matthey & Co.'s stills (sulphuric acid), 95.
Joining indiarubber textures, 1158.
Jones' hydrometer, 215.
—— and Rocke's fleshing-machine, 1225.
—— and Walsh's furnace (soda), 286.
Jonquil extract, 1528, (oil) 1422.
Jordan beater, 1491.
Jouette et Pontièves' process (tartaric acid), 182.
Jouin's cane-slicer, 1880.
Jubæa spectabilis (fibre), 962, (oil) 1385.
Jubbulpore hemp, 947.
Juchtenleder, 1236.
Juchtenöl, 1418.
Juglans alba (timber), 2015–6.
—— regia (dye), 868, (nut) 1360, (oil) 1413.
—— spp. (timber), 2022.
Jugs, glass, 1071.
—— stoneware, 1573.
Jumrasi (resin), 1666.
Jungle-almond-oil, 1396.
Juniper (acetic acid), 14, (oil) 1422, (resin) 1681, (tar) 1684.
Juniperus bermudiana (timber), 2013–4.
—— spp. (gin), 222–3, (oil) 1419, 1422, 1431, (resin) 1624, 1681, 1684.
—— virginiana (timber), 2014.
Jupati oil, 1392
Jusquiame, 812.
Jutahy seca (rubber), 1623, 1641, 1666.
Jute, 940–5.
—— adulterations, 944.
—— beaming, 1184.
—— calendering, 1185.
—— carding, 1178.
—— characters and uses, 945.
—— cultivation, 941–2.
—— drawing, 1180.
—— drawing-in, 1185.
—— extraction of the fibre, 942–3.
—— factories, 1186.
—— finishing, 1185–6.
—— for paper, 1485.
—— manufactures, 1176–86.
—— —— statistics, 1186.
—— manufacturing, 1183–6.
—— roving, 1181–3.
—— sizing, 1185.
—— softening, 1177–8.
—— spinning, 1183.
—— statistics and prices, 945.
—— suggested improvements in preparing, 943.
—— transport and trade, 944.
—— varieties and qualities, 944–5.
—— warping, 1184.
—— weaving, 1185.
—— yield and cost, 943.
Jychee (oil), 1414.

KAFFEE, 691–722.
Kaffir hemp, 960.
Kahikatea wood, 2020.
Kainit, 278.
Kajlee sugar-cane, 1860.
Kakosmanthus macrophyllus (resin) 1665.
Kakul, 1631–2.
Kala dammar, 1644–5.
Kala-til, 1388.
Kalapa oil, 1415.
Kali, 250–79.
Kalisalpeter, 273–7.
Kalong, 1375.
Kama-i-anguza, 1634.
—— -i-gawi, 1634.
Kamal (tannin), 1994.
Kamala, 861, (oil) 1415.
Kameel-boom, 2015.
Kamille, 798–9.
Kaminian, 1637.
Kampher, 571–6.
Kamptulicon, 1015.
Kanari-oil, 1392.
Kandahari-hing, 1633.
Kaneel, 1805–7.
Kane's acidimeter, 145.
Kangaroo-skins, 1758.
Kanya, 1413.
Kanyin (timber), 2016.
Kapur barus, 576–7.
Karamania gum, 1686.
Karaaon, 1676–7.
Karetandjeng, 1652.
Karetmondjeng, 1652.
Karet-pantjal, 1652.
Karródoorn, 1632.
Kartoffelstärke, 1823–6.
Kát (tannin), 1982–3.
Katchang-tanak, 1357–8.
Katiow-oil, 1392.
Katzendarm, 608–10.
Kauri (resin), 1666–7, 2024, (timber) 2016.
Kautschuk, 1142–64, 1627–8, 1654–66.
Kava-kava, 815, 1305.
Kayugaru, 1523–4.
Kayu-glum (oil), 1418.
Kayu-puti, 1418.
Keenatel-oil, 1392.
Kekune-oil, 1392–3.
Kelp, potash from, 263–5.
Kentish cob-nut, 1358.
Kermes, 861.
Kerosene, 1446.
Kersanee oil, 1396.
Kerze, 578–94.
Kesambi-wood, 1394.
Kessaree flowers, 867.
Kestner's apparatus (acetic acid), 20.
Keystone mill, 1227.
Kew Garden bouquet, 1530.
Khassuch plant, 1650.
Kheir, 1632.
Kheu, 1692.
Khoka (narcotic), 1307.
Kid, calf-, 1237.
—— glove-, 1237.
—— -skins, 1757–8.
Kief (narcotic), 1306.
Kiekie (fibre), 948.
Kienruss, 455–6.
Kieselsäures kali, 277–8.
Kifushi (galls), 1984.
Kikuel-oil, 1392.
Kilns, brimstone, 52–3, 56–7.
—— for burning-in stains (glass), 1086.
—— —— pottery, 1563–8.
—— —— revivifying charcoal, 1853–4, 1923–6.
—— —— terra-cotta, 1584–5.
—— pyrites, 80–7.
Kingsland beater, 1491.
Kinmond's tea-rolling machine, 1999.
Kino, 815, 1667–8.
Kiourou oil, 1411.
Kips (E. India), 1234.
Kiri-hinau (tannin), 1993.
Kiri-toa-toa (tannin), 1994.
Kirk's stirrer for paraffin, 1513.
Kirs, 1306.
Kirschgummi, 1638–9.
Kirschwasser, 224.
Kitchen stuff, 1372.
Kittool, 938.
Klein-waaren, 1761–4.
Kluzemann's press for drying exhausted beet slices for cattle-food, 1846.
Knitted fabrics, 1186–1200.
Knitting-needles, 1190.
Knochen, 521–5.
Knochenfett, 1361.
Knochenschwarz, 452–4.
Knopf, 557–71.
Knorpeltang, 814.
Koga wax, 2045.
Kohlensäure, 45–8.
Kohlensäures baryt, 361.
—— kali, 253–60.
—— natron, 279–318.
Kokkelskörner, 808.
Kokoona zeylanica (oil), 1414.
Kokum-butter, 815, 1395.
Kola-nut, 1358–9.
Kolan, 1652.
Kolinski fur, 1031.
Königwasser, 335.
Koosum, 1668, 1669, 1670, 1671.
Kopalharz, 1640–4.
Koralle, 1521–3.
Korarima cardamom, 1804.
Koriander, 1808.
Kork, 722–9.
Kos, 1668.
Koso, 815.
Kotian, 1652.
Kowrie, 1666–7.
Krameria spp. (drug), 820.
Kuhlmann's kiln (sulphuric acid), 57.
Kukui-oil, 1392–3.
Kulit lawang, 1805.
Kulp, 1370–1.
Kümmel, 1803.
Kundoo-oil, 1395–6.
Kunkumas, 1430.
Kunnee gum, 1621, 1651.
Kurung-oil, 1393.
Kus-kus extract, 1529.
Kut (tannin), 1982–3.
Kuteera (gum), 1621, 1685.
Kydia calycina (fibre), 962, (resin) 1668.

LABELS, cement for, 624, 627.
—— inks for, 1172.
Laberie and Berthet's fibre-machine, 929.
Labiatæ, camphor from, 574.
Laboratory lute, 630.
Labrador tea, 1308, (oil) 1430.
Laburnum (acetic acid), 14.
Lac (dye), 861, (resin) 1624, 1625, 1626, 1668–73, 2024, 2025.
—— insect, Indian trees frequented by, 1668
—— Sonora, 1625.
Lacambre et Persac's starch-drier, 1825–6.
Lace, 1200–13.
—— factories, 1212.
—— hand-made, 1200–4.
—— machine-made, 1204–12.
—— statistics, 1212–3.
Lace-bark tree, 962.
Lacrezeira gum, 1650.
Lactaria spp. (resin), 1665.
Lactarine, 1304.
Lactic fermentation, 195–6.
Lactine, 1830, 1903–4, 1970.
Lactuca sativa (oil), 1414.
—— spp. (drug), 815–6.
Lactucarium, 815.
Lætia resinosa (resin), 1624.
Lævo-glucose, 1830, 1831.
Lagerströmia parviflora (resin), 1668.
—— reginæ (timber), 2020.
Lagetta lintearia (fibre), 962–3.
Laine, 2046–7.
Lair et Bilange's elution process for beet molasses, 1859–60.
Lake's artificial indiarubber, 1162.
Lalang grass, 1984.
Lallemantia iberica (oil), 1393.
Lamb skins, 1758.
Lambeth ware, 1570–3.
Lamp-black, 455.
Lamp-worked glass, 1073.
Lamprey-oil, 1376.
Lamy's thallium glass, 1082.
Lan (dye), 862.
Landolphia spp. (rubber), 1627, 1655.
Lapidaries' cement, 624.
Lapis lazuli, 1042.
Laportea pustulata (fibre), 963.
Lapping-machine (indiarubber), 1152.
Laque, 1668–73.
Larch (turpentine), 1691–2, (timber) 2016.
Lard, 1366–7, (oil) 1366–7.
—— rendering, 1447–8.
Lardizabala biternata (fibre), 963.
Larinus spp. (drug), 818.
Larix europæa (oil), 1431.
—— sibirica (resin), 1683.
—— spp. (timber), 2016.
Larrea mexicana (drug), 797, (resin) 1693.
Lasiosiphon speciosus (fibre), 963.
Latches (tanning), 1228.
Lathes, 1561–3.
Laudanum, Dutchman's, 1307.
Laundry soaps, 1789.
Laurel camphor, 572.
—— -oils, 1393, 1422–3.
Laurelia sempervirens, 1812.
Laureline, 862
Laurus camphora (camphor), 571–6.
—— nobilis (oil), 1393, 1422.
—— Peumo (tannin), 1993.
—— Sassafras (drug), 823.
Läusesamen, 798, 826.
Lavandula spp. (oil), 1423.
Lavatera spp. (fibre), 963.
Lavender extracts, 1528.
—— oil, 1423.
—— satchet, 1531.
—— water, 1532.
Lawsonia alba (oil), 1424.
—— spp. (dye), 858.
Lawson's flax breakers, 969.
Laycock's hair loom, 1102.
Layers, 1230.
Laying ropes, 1704–5.
Lead acetate for defecating cane-juice, 1888.
—— acetates, 32, 1300.
—— assay, 355.
—— detection, 349.
—— glass, 1067.
—— mordants, 1300.
—— subacetate, 1300, 1888.
—— vinegar, 1300.
Leaden pans (sulphuric acid), 96.
Leather, 1213–40.
—— anatomical structure of hide, 1213–7.
—— and metal, cement for, 625.
—— —— pasteboard cement, 627.
—— bibliography, 1239–40.
—— calf-kid, 1237.
—— cement for, 625.
—— chemical composition of hide, 1217–8.
—— commerce, 1213.
—— construction of tanneries, 1228–9.
—— currying, 1234–6.
—— dérayage, 1234.
—— drying upper leathers, 1234.
—— dyeing, 1239.
—— elastic fibres of hide, 1218.
—— enamelled, 1236.
—— essorage, 1234.
—— glove-kid, 1237–9.
—— grinding and exhausting tanning materials, 1226–8.
—— hide albumen, 1218.
—— hides used for sole-leather, 1218–9.
—— japanned, 1236, 2032.
—— (upper), measuring, 1235–6.
—— Morocco, 1236.
—— (upper), oiling, 1234–5.
—— patent, 1236.
—— preparation of hides for tanning, 1219–26.
—— retenage, 1234.
—— Russia, 1236–7.
—— samming, 1237.
—— -scouring machine, 1235.
—— sole-leather in the shed, 1231–2.
—— —— —— tan-house, 1229–31.
—— (upper), stuffing, 1234.
—— tannage of dressing-leather, 1232–4.
—— tanning materials, 1226.
—— tawing, 1237.
Lebanon cedar-oil, 1419.
Lebée's beetroot pulp press, 1839.
Leberthran, 1363–5.
Leblanc's process (soda), 106, 280, 289, 311, 312.
Lecanium coffeæ (coffee), 699.
Lecks (tanning), 1228.
Lecythis ollaria (oil), 1414.
—— spp. (nut), 1359.
Ledebouria hyacinthina (drug), 826.

Ledum latifolium (narcotic), 1308.
Ledum palustre (narcotic), 1308, (oil) 1430.
Lefranc and Nagoua's machine (fibres), 925.
Legumine, 2025.
Leinenmanufactur, 1240–55.
Leinöl, 1393–4.
Leiogomme, 1645–7.
Leitch's photo-engraving process, 1618.
Lemonade, 368, 424.
Lemon-grass-oil, 1423.
—— -oil, 1423.
—— salts of, 277.
—— soap, 1791.
Lemons, 1025.
Lenciscus alburnus (pearl), 1521.
Lenses, 1533.
Lens making, 1082.
Leo spp. (fur), 1031.
Leontice thalictroides (dye), 856.
Leontodon spp. (drug), 826.
Leopoldinia Piassaba (fibre), 963.
Lepidium sativum (oil), 1415.
Lepidosperma gladiata (fibre), 963.
Leptandra virginica (drug), 794.
Leptoptilos spp. (feathers), 906.
Leptospermum spp. (tea), 2010, 2011.
Lepus spp. (fur), 1031, 1032.
Letter-fixing cement, 627.
—— -press printing, 1601–4.
Lettuce (oil), 1414, (opium) 815.
Leucadendron Cajuputi (oil), 1418.
Leucaniline, 662.
Leuconotis sp. (resin), 1658.
Leucoperca Sandre (oil), 1376.
Levantische Gallen, 1983–4.
Levers' lace-frame, 1207.
Liban (resin), 1676.
Libi-dibi, 1983.
Libocedrus spp. (timber), 2014.
—— tetragona (timber), 2012.
Licht, 578–94.
Lichtbildkunst, 1532–44.
Lichtmessung, 1544–7.
Licuala spp. (resin), 1648.
Liége, 722–9.
Light naphtha, 1446.
Light, polarized, 1956–62.
—— table of cost of, 1547.
Lignaloe extract, 1529.
Lignum-aloes, 1523–4, 1624.
—— -vitæ (drug), 816, (timber) 2016–7.
Ligustrum spp. (wax), 2044, 2045.
Lilac (extract), 1528, (oil) 1424.
Lilpop's osmogene, 1859.
Lily-of-the-valley extract, 1528.
Lime (earth), 232.
—— acetate, 34.
—— —— acetic acid from, 22–3.
—— aceto-chloride, acetic acid from, 24–5.
—— and carbonic acid process for defecating beet-juice, 1846–9.
—— bisulphite for defecating cane-juice, 1887–8.
—— carbonate and carbonic acid table, 1969.
—— chloride utilization (bleaching powder), 468.
—— for bleaching powder, 459–60.
—— for defecating cane-juice, 1886–7.
—— blossom extract, 1529.
—— in sugar-cane soils, 1864–5.
—— kiln for carbonating beet-juice 1847–8.
—— for soap-making, 1768–9.
—— oxalate, 161.
—— removal of from fats, 1460.
—— sucrates, 1943.
—— —— process (beet molasses), 1859–60.
—— —— —— (sugar-refining), 1930–3.
—— scums, filter presses for, 1848–9.
—— —— removal from beet-juice, 1848–9.
—— —— utilization, 1848.
—— juice, 49, 816.
—— -tree bast, 998.
—— —— oil, 1424.
—— —— wood (acetic acid), 15.
Limes (fruit), 1025.
Limeing hides, 1220.
—— -machine (bleaching), 478.
Limestone, assay, 360.
Limoges ware, 1599.
Linden (acetic acid), 14–15, (oil) 1424.
Linen-bleaching, 515.
—— —— chemicking-machine, 515.
—— —— cloth, 515–6.
—— —— process for brown linen, 516–7.
—— —— —— for cream linen, 517–8.
—— —— rubbing-machine, 516.
—— —— squeezers, 515.
—— dressing and sorting, 1246–7.
—— factories, statistics, 1255.
—— for paper, 1485.
—— machine hackling, 1244–6.
—— manufactures, 1240–55.
—— —— bibliography, 1255.
—— —— distribution, 1240–3.
—— —— history, 1240–3.
—— —— modern, 1243–55.
—— —— statistics, 1255.
—— —— tow preparation, 1251–2.
—— preparing, 1247–9.
—— reeling, drying, and bundling, 1253–4.
—— roughing, 1243–4.
—— roving, 1249–51.
—— spinning, 1252–3.
—— weaving, 1254–5.
—— yarn bundling, 1254.
—— —— drying, 1254.
—— —— reeling, 1253.
—— —— table, 1254.
Lines, 1696.
Ling (nut), 1359, (oil) 1364.
Linoleum, 1001–15.
—— applying to canvas, 1007–9.
—— cork for, 1001–2.
—— hand-printing, 1009–13.
—— machine-printing, 1013–5.
—— mixing ingredients, 1006–7.
—— oxidized linseed-oil, 1002–6.
—— seasoning, 1009.
Linseed-oil, 1393–4, 2024.
Linum usitatissimum (fibre), 964–78, (oil) 1393–4.
Lion fur, 1031.
Liqueur de ferraile, 31–2.
Liqueurs, 224.
Liquid glue, 622.
—— storax, 826, 1626, 1682.
Liquids [greasy], recovery of grease from, 1455–6.
—— specific gravity of, 2.
Liquidambar, American, 1682–3.
—— East Asian, 1683.
—— spp. (resin), 1624, 1626, 1682–3.
Liquidation of soap, 1780.
Liquorice, 816.
Lisbon water, 1532.
Lithia, 250.
—— water, 367.
Lithography, 1614–6.
—— chromo-, 1604–6.
Lithospermum erythrorhizon (dye), 867–8.
Litmus, 862.
Litsæa spp. (oil), 1415.
Livistona australis (fibre), 946.
—— sinensis (oil), 1415.
Llama hair, 1093, (skins) 1758.
Loban (resin), 1675.
Locomotive-grease, 1797–8.
Locust-tree, 2017.
—— American, 2012.
Logwood (acetic acid), 14, (dye) 817, 862.
Long nutmeg, 1812.
—— pepper, 1814.
Longs of flax, 1244.
Looms for hair cloth, 1101.
Lopez-root, 817.
Lord's combined opener, &c. (cotton manuf.), 740.
—— piano-feed scutcher (cotton manuf.), 742.
Lota spp. (oil), 1364.
Louar-oil, 1369–70.
Löwenzahn, 826.
Low-press kier (bleaching), 485.
Loxopterygium Lorentzii (tannin), 1988.
Lubán jáwi (resin), 1637.
Luban-mati (resin), 1676.
Lubricating values of oils, 1479–81.
Lubricators, 1797–8.
Luce, eau de, 1532.
Lucifers, 1277–92.
Luck's test (anthraquinone), 652.
Lucrabau-oil, 1382.
Lucuma Bonplandii (oil), 1395.
—— mammosa (oil), 1415.
—— spp. (resin), 1694.
Lukrabo-oil, 1382.
Lulu (oil), 1410.
Lumbang-nut, 1352.
Luteoline, 868.
Lutes, 628.
Lutra spp. (fur), 1032.
Lycopodium spp. (drug), 817.
Lycopus europæus (oil), 1432.
Lydus spp. (drug), 797.
Lygeum Spartum (fibre), 978–9.
Lyncus spp. (fur), 1031.
Lynx fur, 1031.
Lysiloma Sabicu (timber), 2020.
Lytta spp. (drug), 796–7.

MABA guianensis (timber), 2021.
Mabo-oil, 1394.
Maçaranduba blanca (resin), 1694.
Macaranga spp. (resin), 1694.
—— tomentosa (resin), 1665.
Macassar-oil, 1394, 1410, 1422.
Mace, 1810–2.
—— oils, 1396–7, 1424, 1811.
Maceration processes for extracting beet-juice, 1839–42.
—— —— —— essential oils, 1458–9.
—— —— sugar-cane, 1879.
Machærium fertile (tannin), 1988.
—— spp. (timber), 2020.
Machine knitting needles, 1190.
—— -made cordage, 1697–1704.
—— —— lace, 1204.
—— for moulding terra-cotta, 1586.
—— salt-pans, 1734–6.
Macis, 1810–12
Maclura aurantica (dye), 864, (oil) 1415.
M'Lean & Angus' kiln for revivifying charcoal, 1923–4.
M'Naught's (J. & W.) wool-scouring machine (bleaching), 509.
Macrobasis albida (drug), 796.
Macrochloa tenacissima (fibre), 979–81.
Mactear's aspirator, 133.
—— carbonator (soda), 300.
—— process (soda), 313.
Madagascar nutmeg, 1812.
—— rubber, 1627, 1654.
Madder, 862.
—— bleach, 471.
—— —— alteration in weight, &c., of calico pieces, 487.
—— —— ancient and modern processes compared, 488.
—— —— arsenic solution, 484.
—— —— chemicking, 482.
—— —— final washing, 482.
—— —— indigo indicator solution, 484.
—— —— kiers, 485–6.
—— —— limeing, 481.
—— —— lime or grey sour, 481.
—— —— lime washing, 481.
—— —— notes on chemicking, 484.
—— —— —— grey washing, 482.
—— —— —— lime boil, 482.
—— —— —— limeing, 482.
—— —— —— resin boil, 483–4.
—— —— —— souring, 483.
—— —— —— white sour, 485.
—— —— opening and drying, 492–4.
—— —— proposed new bleaching agents, 486–7.
—— —— quantities of agents best suited, 488–9.
—— —— resin or ley boil, 482.
—— —— second boil in soda ash, 482.
—— —— singeing, 472–7.
—— —— squeezing, 489–92.
—— —— stains, 487.
—— —— stamping, 471.
—— —— stitching, 471–2.
Madder, bleach, tensile strengths of cotton threads, 487.
—— —— test solutions for use, 484–5.
—— —— washing, 481.
—— —— washing after ley boils, 482.
—— —— washing after lime sour, 481–2.
—— —— white sour, 482.
—— lake, 1550.
—— oxalic acid from, 172.
Madia sativa (oil), 1394.
Madjendel (resin), 1676.
Madjoun (narcotic), 1307.
Madrepora virginea (coral), 1521.
Magdala pink, 681.
Magenta, 660.
—— residues, 662.
Magnesia water, 367.
Magnolia extract, 1529.
Maguey gum, 1638.
Maheri (resin), 1676.
Mahogany, 2017.
—— African, 2017.
—— Australian, 2016.
—— Ceylon, 2016.
—— East Indian, 2017.
—— gum, 1673.
—— lute, 630.
Mahwa oil, 1394.
Mahwal fibre, 921.
Maissiat's lute, 630.
Maize-oil, 1415, (starch) 1823, (sugar) 1908–14.
Majert's (W.), process (sulphuric anhydride), 98.
Majolica ware, 1599.
Makar (resin), 1677.
Malabar-oil, 1367.
Malacca rubber, 1664.
Malachra capitata (fibre), 981.
Malagueto de montana (oil), 1377.
Malapajo balsam, 1652.
Malay Archipelago rubber, 1664.
—— camphor, 576.
Malden island guano, 1265.
Male fern, 811, (oil) 1414.
—— nutmeg, 1812.
Mallotus philippinensis (dye), 861, (oil) 1415.
Malpighia punicifolia (tannin), 1994.
Malt, 207.
—— crushing (vinegar), 2038.
—— grinding (alcohol), 207.
—— infusion (alcohol), 208–10.
—— mashing (alcohol), 207–8, (vinegar) 2039.
Malting, 379.
Maltose, 1830, 1831.
Malva spp. (fibre), 982.
Mamey-oil, 1394–5.
Mammoth-ivory, 1175.
Manatee-oil, 1367–8, (skins) 1757.
Manatus spp., 1367–8, 1757.
Manbré's methods (starch-sugar), 1918.
Manchester brown, 670.
—— yellow, 682.
Manchot (oil), 1376.
Mancona, 823.
Mandioc, 1828.
Mandragora spp. (drug), 794.
Manfold's sugar-cane sawdust method, 1879.
Mangabeira rubber, 1627, 1664.
Manganese acetate, 36.
—— assay, 355.
—— brown, 37.
—— detection, 349.
—— green, 1549.
—— mordants, 1300.
—— ores for bleaching-powder, 458.
—— regenerating (bleaching-powder), 461–8.
—— replacing (bleaching-powder), 468–70.
Mangifera indica (resin), 1668, 1673, (shade) 1812, 1815, (timber) 2017.
Mango (gum) 1673, (shade) 1812, 1815, (timber) 2017.
Mangold fly, 1835.
Mangosteen-oil, 1395.
Mani (resin), 1625, 1654.
Manicaria saccifera (oil), 1415.
Manifold writers, 1608–10.

Manihot Glaziovii, 1658–9.
—— spp. (starch), 1828.
Manilla elemi, 1649.
—— hemp, 983.
—— —— characters and uses, 984–5.
—— —— cultivation, 983.
—— —— exports and values, 985.
—— —— extraction, 983–4.
—— nut, 1357–8.
—— tamarind-oil, 1415.
Manioc, 1828.
Manipulative processes (pottery), 1576–81.
Manlove & Co.'s cane-mill, 1875.
Manna, 817.
Mannings' process (ammonia), 233.
Mannite, 1830.
Mann's chromo-litho machine, 1606–7.
Manoury's lime-sucrate process for beet molasses, 1860.
Manquitta (tannin), 1994.
Manuel et Socin's beetroot pulp press, 1839.
Manufacturers' soaps, 1788–9.
Manungan (resin), 1658.
Manures, 1256–77.
—— animal charcoal, 1266.
—— [artificial], basis of value, 1276.
—— bibliography, 1277.
—— blood, 1257–8.
—— bone-ash, 1266.
—— bones, 1256–7.
—— cinchona, 803.
—— coffee, 697–8.
—— commerce, 1276–7.
—— cotton, 957.
—— crushing phosphates, 1267–8.
—— fish, 1257.
—— flesh, 1257.
—— general considerations, 1276.
—— grinding phosphates, 1268.
—— guano, 1258–9.
—— manufacture of artificial, 1267–71.
—— mineral phosphates, 1259–65.
—— mixing, 1268–71.
—— (artificial), packing, 1271.
—— poudrette, 1271–2.
—— prevention of nuisance in making, 1272–6.
—— produced on sugar estates, 1865.
—— screening, 1271.
—— scutch, 1266–7.
—— "setting" and "going back," 1270.
—— shoddy, 1266.
—— sugar-beets, 1833.
—— sugar-canes, 1863–6.
—— sugar-scum, 1266.
—— sulphate ammonia, 1259.
—— superphosphates, 1259–71.
—— tea, 1997.
—— tobacco, 1326–7.
Maoutia puya (fibre), 932.
Maple (acetic acid), 14.
—— great (timber), 2021.
—— -sugar, 1902–3.
—— -wood, 2017.
Maracaibo phosphate, 1264.
Marais salants or salins, 1716.
Maranta obliqua (fibre), 982.
—— spp. (starch), 1822–3.
Marble cement, 627.
—— cement for, 625.
—— lute, 630.
Marbling book-edges, 1686.
Maréchal bouquet, 1530.
—— satchet, 1531.
Mares'-grease, 1366.
Marfil vejetal, 1357.
Margarine-Mouries, 1362–3.
Margosa-oil, 1395.
Marie's begass furnace, 1876–7.
Marima (fibre), 919.
Marine glue, 625.
—— plants, potash chloride from, 263–5.
Marinhas (salt), 1716.
Marjoram-oil, 1424.
Market-bleaching, 495–506.
—— beetling, 499–501.
—— calendering, 498–9.
—— damping, 497–8.
—— dash-wheels, 495.
—— folding, 501–4.
Market hydro-extractor, 495–6.
—— muslin finishing, 504–6.
—— starching, 496–7.
Marking-inks, 1168.
Marrem (fibre), 994.
Marriotte vessel (sulphuric acid), 58.
Marsdenia tenacissima (fibre), 982.
Marsh gladden (fibre), 996.
—— ledum, 1308.
—— -mallow soap, 1790.
Marten fur, 1031.
Mascati (resin), 1676.
Mashing (vinegar), 2039.
Massaranduba (resin), 1664.
Masson & Scott's esparto-picking machine, 1486.
Mastic, 1623, 1624, 1625, 1644, 1673–4, 2024, (brandy) 1673.
Masticating indiarubber, 1144.
Mastix, 1673–4.
Matches, 1277–93.
—— compositions, 1292–3.
—— cutting and filling machines, 1286–92.
—— dipping, 1281.
—— filling and dipping, 1279–92.
—— splint-pointing, 1282–5.
—— splints and splint-cutting, 1277–9.
—— vestas, 1292.
—— vesuvians, 1292.
Matal wood, 2019.
Materials for terra-cotta, 1583.
Mather's condenser (hydrochloric acid), 142.
Mati (resin), 1676.
Matico, 818, (oil) 1424.
Matières tannantes, 1977–94.
—— tinctoriales, 854–69.
Matricaria Chamomilla (drug), 799.
Mat-rush, 999.
Maumené's test for oils, 1471.
Mauritia flexuosa (fibre), 982.
—— spp. (oil), 1415.
Mauritius elemi, 1649.
Mauvaniline, 668.
Mauveine, 666.
May flowers bouquet, 1530.
—— grass (perfume), 1528.
Meadow-saffron, 808.
—— -sweet-oil, 1424.
Meat, preserving, 1018–22.
Mecca balsam, 1625, 1636.
Meersalinen, 1716.
Meer-salz, 1714–9.
Meerschaum, 640.
—— cement for, 627.
Meerzwiebel, 825–6.
Megass furnaces, 1876–7.
Mebudee-oil, 1424.
Mejillones guano, 1265.
Melaleuca Leucadendron (drug), 795.
—— spp (oil), 1418, (tea) 2010.
Melanorrhœa usitatissima (resin), 1692.
Meleagrina margaritifera (pearl), 1517, 1519.
Meles spp. (fur), 1030.
Meleziton, 1830.
Melia Azadirachta (oil), 1395, (timber) 2018.
—— Azedarach (resin), 1621.
—— spp. (resin), 1694.
Melilot, 1528.
Melilotus cæruleus (perfume), 1528.
Melissa-oil, 1417.
—— [Indian] oil, 1423.
Melitose, 1830.
Melodinus monogynus (fibre), 982.
Meloë spp. (drug), 797.
Melolontha spp. (drug), 796.
—— vulgaris (oil), 1375.
Melon-oil, 1361, 1395.
—— -sugar, 1903.
Melting- and resolidifying-points of mixtures of stearic and palmitic acids, 1464.
Mendings, 1762–3.
Mendora (resin), 1694.
Mendrina cerebriformis (coral), 1521.
Menhaden-oil, 1368.
Menispermum Cocculus (drug), 808.
Mentha piperita (drug), 819, (oil) 1425–7.
Mentha Pulegium (drug), 819.
—— spp. (oil), 1427.
—— viridis (oil), 1431.
Menthe-poivree, 819.
—— -pouliot, 819.
Menungan (resin), 1657.
Menyanthes trifoliata (hops), 1131.
Menzies' & Davies' smell-consumer, 1506–7.
Mephitis americana (fur), 1033.
Mercurialis annua (oil), 1432.
Mercury acetate, 37.
—— assay, 356.
—— detection, 349.
Merryweather's apparatus (candles), 581
Mesphilodaphne Sassafras (drug), 823.
Mesquit, 1674.
Messel's process (sulphuric anhydride), 97.
Mesua ferrea (dye), 864, (oil) 1415, (perfume) 1526, (resin) 1694.
Metal buttons, 557.
—— glass, and wood, cement for, 625.
Metallic cement, 627.
—— surface, inks for, 1172.
Metals, corrosive action of oils on, 1481.
—— and glass, cement for, 625, 627.
—— wood, and indiarubber, cement for, 626.
Methyl-aniline, 567.
—— —— green, 669.
—— benzols, 618.
—— -benzyl-diphenyl-amine, 659.
—— -diphenyl-amine, 659.
—— -rosanilines, 667.
Methylated spirit, 214.
Metrosideros lucida (timber), 2020.
Metroxylon spp. (starch), 1827–8.
Mexican aloe, 912.
—— blue, 863.
—— dragon's-blood, 1648.
—— elemi, 1649.
—— fibre, 985, 1101.
—— gum, 1635, 1639.
Mézéréon, 818.
Mezquite, 1621, 1674.
Mhor (oil), 1371.
Mhowa (oil), 1394.
Michelia Champaca (oil), 1422, (resin) 1694.
Microclados olecrum (oil), 1482.
Micro-photographic camera, 1535.
Microcosmic salt, 316.
Middles, &c., of flax, 1246.
Mignon et Rouart's cane defibrator, 1878.
Mignonette-oil, 1424.
Milfoil-oils, 1424.
Milk-preserving, 1016.
—— -sugar, 1830, 1903–4, 1970.
Millefleur satchet, 1531.
—— soap, 1791.
Milner's salt-pan, 1737–8
Mimosa-bark, 1226, 1986–7.
—— cinerea (resin), 1668.
—— spp. (resin), 1632, (tannin) 1982–3, 1986–7
Mimulus moschatus (musk), 1525.
Mimusops Balata (resin), 1635–6, 1639, (timber) 2013.
—— elata (resin), 1664.
—— Elengi (resin), 1694.
—— spp. (oil), 1415, (resin) 1627.
Minderus, spirit of, 29–30.
Mineral impurities in fats, estimating, 1462.
—— matters in cane-juice, 1872.
—— oils, 1433–47.
—— —— in fats, detection of, 1466.
—— —— in mixed oils, estimation of, 1467–9.
—— phosphates, 1259.
—— —— alum from, 329.
—— —— crushing, 1267.
—— —— grinding, 1268.
—— tar, 1433–47.
Mink fur, 1031.
Minton's pottery oven, 1564.
Minyak-katjang, 1357–8.
Miro timber, 2017.
Mishmi-bitter, 809.
Miso (oil), 1378.
Mispickel, 40.
Mitis green, 31.
Mixing and grinding rubber, 1149.
—— artificial manures, 1268.
—— cotton, 737.
—— mill (gunpowder), 887.
—— soap, 1785–6.
—— wine, 441.
Mnangu, 1641.
Mochras (resin), 1674.
Mochurrus (resin), 1674.
Modelling terra-cotta, 1585–6.
Modiola vulgaris (pearl), 1517.
Mœrman-Laubuhr's apparatus (fibre), 928.
Mogador gum, 1632.
Mohair, 1095.
Mohn, 820.
Mohnöl, 1409.
Mohrs (resin), 1676–7.
Mohr's burette, 27.
—— lute, 630.
Moisture in fats, estimating, 1462.
Mojrus (resin), 1674.
Mola plum (oil), 1394.
Molasses, alcohol from, 203.
—— beet, 1858–60.
—— —— carbonate potash from, 257–9.
—— —— chloride potash from, 266.
—— —— sulphate potash from, 278.
—— definition, 1831.
—— elution process for, 1859–60.
—— graining, 1895.
—— oxalic acid from, 163–4.
—— treatment by osmosis, 1858–9.
Moldavian balm, 1417.
Moll (resin), 1648.
Molinier's fleshing-machine, 1225.
Momeca (narcotic), 1306.
Monarda didyma (tea), 2011.
Mond's process (soda), 312.
Mondollot's apparatus (aerated waters), 375.
Monk's Island phosphate, 1264.
Monkey-bread (fibre), 912.
—— fur, 1032.
—— musk, 1525.
—— nut, 1357–8.
—— pots, 1359.
Mono-amyl-aniline, 658.
—— -phenyl-rosaniline, 667.
Monodon monoceros (ivory), 1175.
Monodora grandiflora (oil), 1415.
—— Myristica, 1812.
Monrovian oil, 1407.
Monte-jus, 1883–4.
Montpellier bouquet, 1531.
Mooda hoora oil, 1365.
Moodooga-oil, 1395.
Mooi (gum), 1651.
Moonga silkworms, 1745.
Moonyah (fibre), 919.
Môr (resin), 1674.
Mora excelsa (timber), 2017–8.
Moram (fibre), 994.
Mordants, 31, 1293–1305.
—— alumina, 1295–6.
—— antimony, 1296.
—— arsenic, 1296.
—— bismuth, 1296.
—— chromium, 1296–7.
—— copper, 1297.
—— iron, 1297–1300.
—— lead, 1300.
—— manganese, 1300.
—— organic, 1303–5.
—— silica, 1300.
—— sulphur, 1300–1.
—— tin, 1301–3.
—— zinc, 1303.
Moreton Bay chestnut, 1353.
Morfit's steam-twirl (soap), 1771–3.
Morinda spp. (dye), 858.
Moringa gum, 1621, 1674.
—— pterygosperma (oil), 1378–9, (resin) 1621, 1674.
—— spp. (oil), 1378–9.
Morocco ammoniacum, 1630.
—— gum, 1621, 1632.
—— leather, 1236.
Moronobea coccinea (resin), 1624, 1654.
Morphia, 231.
Morphine, 231.

Morris and Griffin's bone-boiler, 1449.
Mortar, 618.
Morung elachi (spice), 1804.
Morus tinctoria (dye), 857–8.
Mosaic glass for windows, 1084.
—— pavements, 1587–94.
Moschatel, 1525.
Moschoxylum Swartzii (perfume), 1525.
Moschus, 826, 1524–6.
—— moschatus (perfume), 1524, 1525–6.
Mosqueit, 1674.
Moss-rose extract, 1529.
Mosul gum, 1686.
Mote-grease, 1395–6.
Mothay and Rossi's ice-machine, 1141.
Mother-of-pearl, 1516–21.
Mottled soaps, 1780.
—— blue-, grey-, and red-, soaps, 1787–8.
Mottling buttons, 563.
Moulding and banking sugar-canes, 1867.
—— cylinders (glass), 1066.
—— indiarubber, 1160.
—— soap, 1783–4.
Moulds for earthen-ware, 1577–8.
Mountain flax, 945.
—— green, 31, 1549.
Mousseline, eau de, 1532.
—— satchet, 1531.
Moutarde, 1810.
Mozambique rubber, 1627, 1654.
M'Poga (oil), 1396.
Msandarusi (copal), 1641.
Mucherus (resin), 1674.
Mucuna sp. (drug), 795.
Mudar (fibre), 933.
Muffles for pottery, 1563–8.
Muga silkworms, 1746–7.
Mugwort-oil, 1424.
Mühl's ice-machine, 1136.
Mujankuri silkworm, 1747.
Mukul (resin), 1636.
Mulberry (fibre), 858.
Mule (cotton manuf.), 754.
Müller-Jacob's process (mordants), 1304.
Mulmul (resin), 1674.
Multicolour press, 1605.
Multiple effect vacuum-pans, 1895–8.
Mungo, 2058.
Munjeet (dye), 863.
Muntz's metal, 323.
Muræna Congre (oil), 1375.
Murdoch's sugar-cane disintegrating process, 1879.
Mure's hemp-breaker, 936.
Muriate alumina, 1296.
—— antimony, 1296.
—— copper, 1297.
—— iron, 1298.
—— tin, 1301.
Murraya Königii (oil), 1410.
Murray's silk-spinning machine, 1753.
Murucuja ocellata (narcotic), 1307.
Mus cricetus (fur), 1031.
Musa paradisaica (starch), 1823.
—— sapientum (fibre), 982.
—— spp. (fibre), 982–5, (fruit) 1022–3.
—— textilis (fibre), 983.
Musc, 1524–6.
Muscades, 1810–2.
Muscovado sugar, 1900.
Musk, 1524–6.
——-beetle, 1525.
—— -deer, 1524, 1525–6.
—— -duck, 1525.
—— extract, 1529.
—— -ox, 1525.
—— -plant, 1525.
—— -rat, 1032–1525.
—— —— (Indian), 1525.
—— root, 826, 1525.
—— -wood, 1525.
Muskatblüthe, 1810–2.
Muskatbutter, 1396–7.
Muskatnüsse, 1810–2.
Muskatnussöl, 1396–7.
Muslin-de-laine bleaching, 513.
Musquash, 1032, 1525.
Mussel pearl, 1517.
Mustagi-rúmí (resin), 1673.
Mustard, 1810.
—— oil, 1396, 1424.
Mustela spp. (fur), 1030, 1031.
Muter's oleine-tube, 1463–6.
Mutterharz, 1650.
Mutterkorn, 810.
Mutti wood, 2018.
Myagrum sativum (oil), 1390.
Mycoderma aceti (fungus), 6.
Mycose, 1830.
Mylabris spp. (drug), 797.
Myopotamus coypus (fur), 1032.
Myrcia acris (oil), 1417.
Myrica cerifera (candles), 586.
—— Gale (oil), 1421.
—— spp. (wax), 2045–6.
—— waxes, 2045–6.
Myristica Bicuhiba (oil), 1379, (wax) 2046.
—— malabarica (oil), 1409.
—— sebifera (oil), 1377.
—— spp. (oil), 1396–7, 1415, 1424, (spice) 1810–2.
Myrmecocystus mexicanus (honey), 1128.
Myrobalans, 1226, 1987, (oil), 1396.
Myrobroma fragrans (spice), 1814–6.
Myrocarpus fastigiatus (resin), 1678.
Myrosma indica (dye), 860.
Myrospermum Pereiræ (drug), 819.
—— spp. (resin), 1623, 1677–8.
—— toluiferum (resin), 1684–5.
Myroxylon Pereiræ (drug), 819.
—— peruiferum (oil), 1416.
—— punctatum (resin), 1684.
—— spp. (resin), 1677–8.
—— toluifera (resin), 1684–5.
Myrrh, 1623, 1627, 1674–5, (oil) 1424.
Myrtle extract, 1529.
—— oil, 1424.
—— waxes, 2045–6.
Myrtus communis (oil), 1424.
—— Pimenta (oil), 1416, (spice) 1814.

NAGASAR (perfume), 1526.
Nagdana (resin), 1675.
Nageia Putranjiva (oil), 1415.
Naghas (perfume), 1526.
Naghua (resin), 1676.
Nag-kassar (dye), 864, (oil) 1415, (perfume) 1526.
Nan-mu timber, 2018.
Napa oleifera (oil), 1384–5.
Naphtha, 644, 1433–47, 2026.
—— wood, 35.
Naphthalene, 649.
—— chlorides, 650.
—— derivatives, 681.
—— yellows, 682.
Naphthylamine, 650.
—— violet, 681.
Naples yellow, 1551.
Napping hats, 1120.
Narbuth's flax-breaker, 970.
Narcissus extract, 1529.
—— Jonquilla (oil), 1422.
Narcotics, 1305–51.
—— ava, 1305.
—— betel-pepper, 1305.
—— bhang, &c., 1305–7.
—— bibliography, 1351.
—— bull-hoof, 1307.
—— coca, 1307–8.
—— emetic holly, 1308.
—— ledum, 1308.
—— opium, 1308–24.
—— pituri, 1324.
—— rhododendron, 1324.
—— Siberian fungus, 1324.
—— steppe rue, 1324.
—— thornapples, 1325.
—— tobacco, 1325–50.
—— tumbeki, 1350.
Nardostachys Jatamansi (musk), 1525.
Narthex asafœtida (resin), 1624–33.
Narwhal-ivory, 1175.
Nassau phosphates, 1263.
Nasturtium-oil, 1425.
Natterer's apparatus (carbonic acid), 46.
Natural varnishes, 1692.
Naturalists' cement, 626.
Naucite (tannin), 1994.
Nauclea Gambier (tannin), 1984–5.
Naugiia timber, 2018.
Navassa phosphate, 1264.
Navel-tree gum, 1693.
Neat soaps, 1770–84.
Neat's-foot-oil, 1368.
Nectrandra spp. (resin), 1640, (starch) 1823, (timber) 2015.
Needle-lace, 1201.
Needles, machine-knitting, 1190.
Neem-oil, 1395.
Neem wood, 2018.
Negundo fraxinifolium (sugar), 1903.
Nelkenköpfe, 1814.
Nelkenpfeffer, 1814.
Nepal aconite, 791.
—— cardamoms, 1804.
—— paper-shrub, 947.
—— sugar cane, 1860.
Nephelium Litchi (resin), 1668.
Nerium suaveolens (resin), 1694.
—— tinctorium (dye), 858.
Neroli camphor, 578.
—— extract, 1529.
—— -oil, 1425.
Nessler's test (ammonia), 248.
Nettles (fibre), 963, 999.
Neugewürz, 1814.
Newall and Barker's bark mill, 1227.
New-mown hay bouquet, 1531.
New Zealand cabbage-tree, 945.
—— —— copal, 1666–7.
—— —— flax [hemp], 986–93.
Ngai camphor, 577.
Ngiatos (guttapercha), 1652.
Nicholson's blue, 665.
Nickel, assay, 351.
—— detection, 349.
—— -plating, 880.
Nicotiana spp. (narcotic), 1325–50, (oil) 1411.
Nidularium karatas (fibre), 985.
Niépce's photo-engraving process, 1618.
Nies Hout wood, 2021.
Nieswurzel, 812.
Nigella sativa (oil), 1415, 1432.
Niger oil, 1396.
Night-lights, 594.
Nightsoil as manure, 1271.
Niin-oil, 1368–9.
Niko (oil), 1394.
Nipa fruticans (fibre) 985, (resin) 1658, (sugar) 1904.
Nipis de Piña (fibre), 918.
Nitrates, 153, 160.
—— alumina, 1296.
—— baryta, 361.
—— copper, 1297.
—— iron, 1298.
—— potassium, 273.
—— potash, assay, 360.
—— sodium, 315.
—— tin, 1302.
Nitric acid, 148–60.
—— —— anhydrous, 159.
—— —— characters, 148–50.
—— —— in sulphuric acid, 70.
—— —— manufacture, 154–9.
—— —— occurrence, 150–4.
—— —— red fuming, 159.
—— —— specific gravity, 4.
—— —— supply to sulphuric acid chambers, 58–60.
—— —— testing, 159–60.
Nitric anhydride, 159.
Nitrification, 150, 273.
Nitro-benzols, 654.
—— -compounds anthraquinone, 654.
—— -glycerine compounds, 897.
—— -naphthalenes, 650.
—— -toluols, 654.
—— -xylols, 654.
Nitrogen as ammonia, determination, 249–50.
—— compounds, recovery of (sulphuric acid), 72.
Nocha (oil), 1394.
Noir animal, 452–3.
—— de Francfort, 454–5.
—— de fumée, 455-6.
—— d'ivoire, 455.
Noir d'os, 453-4.
Noix de Galle, 1983–4.
—— Isagur, 822.
Nordhausen acid, 51.
Norwegian apatite, 1261.
Nosegays, 1530–1.
Nose-hole furnace (glass), 1064.
Nounga fat, 1396.
Noxa (oil), 1394.
Noxious vapours prevention (acetic acid), 12–13.
—— —— —— (hydrochloric acid), 118–46.
—— —— —— (manures), 1272–6.
—— —— ——(sugar-refining), 1926.
Noyeaux, 227.
Nuisance. See noxious vapours.
Nunnari-root, 823.
Nürnberger-waaren, 1761–4.
Nut-galls, 1983–4.
Nutmeg-butter, 1396–7, 1811.
—— -oil, 1424.
—— [American] oil, 1377.
Nutmegs, 1810–2.
Nutria fur, 1032.
Nuts, 1351–60.
—— areca, 1351.
—— bibliography, 1360.
—— boma, 1351.
—— Brazil, 1351–2.
—— bread, 1352.
—— candle, 1352.
—— cashew, 1352.
—— chestnut, 1352–3.
—— coco-nut, 1353–7.
—— coquilla, 1357.
—— corozo, 1357.
—— gingko, 1357.
—— ground, 1357–8.
—— hazel, 1358.
—— hickory, 1358.
—— imports, 1360.
—— kola, 1358–9.
—— palm, 1359.
—— physic, 1359.
—— pistachio, 1359.
—— sapucaya, 1359.
—— singhara, 1359.
—— soap, 1360.
—— walnut, 1360.
Nutzholz, 2012–23.
Nux-vomica, 819.

OACA (resin), 1693.
Oak (acetic acid) 14–5, (potash) 255, (timber) 2018.
—— -barks, 1226, 1987–8.
—— -galls, 1983–4.
Objectives, 1533.
Ochoco-oil, 1397.
Ochroma Lagopus (fibre), 986.
Ocimum basilicum (oil), 1415.
Ocuba wax, 2046.
Oculina virginea (coral), 1521.
Ocymum pilosum [basilicum] (fibre), 986.
Odal-oil, 1397.
Odina spp. (resin), 1621, 1651.
Oele, 1360–1484.
Oelsüss, 1798–1802.
Oelzucker, 1798–1802.
Oenanthe Phellandrium (oil), 1432.
Œnocarpus Bacaba (fibre), 986.
Ogadioka (oil), 1395.
Ogea-tree (resin), 1650.
Ognon marin, 825–6.
Oil analysis, examples of, 1475–6.
Oil-bird, 1376.
Oil-cake machinery, 1451–4.
Oilcloth, 1001.
Oiled silk, 2032.
Oil-mill machinery, 1451–4.
Oil of turpentine, 1688–91.
—— of vitriol, 101.
Oil-palm (fibre), 948, (oil) 1406–8.
Oil-tanks, 1445–6.
Oil-tree, 1411–2.
Oiling upper-leathers, 1234–5.
Oils and fatty substances, 1360–1484.
—— animal, fish, and insect, 1361–77.
—— bibliography, 1483–4.
—— boiling, oxidizing, and vulcanizing, 1482, 2029–31.

Oils and fatty substances, detection and analysis, 1462–77.
—— heating values, 1478–9.
—— illuminating values, 1477–8.
—— imports, 1482–3.
—— improved modes of extraction, 1447–59.
—— lubricating values, 1479–81.
—— mineral, 1433–47.
—— prices, 1483.
—— refining, clarifying, and bleaching, 1459–62.
—— tables of actual densities of, 1469–70.
—— varnishes, 2032–5.
—— vegetable fatty, 1377–1415.
—— vegetable volatile, 1415–33.
Oils, 578, 583, 1360–1484.
—— as mordants, 1304.
—— boiled, 2029–31.
—— clarifying, 2024.
—— correcting rancidity in, 1461.
—— corrosive action of, on metals, 1481.
—— decolorizing, 1461–2.
—— deodorizing, 1461.
—— drying (varnish), 2023–4.
—— [mixed], examination of, for mineral and rosin oils, 1467–9.
—— [essential], expression of, 1457.
—— [vegetable fixed], extraction of, 1451–5.
—— [essential and volatile], extraction of, 1456–9.
—— [essential], extraction of, by maceration, 1458–9.
—— for soap-making, 1766–7.
—— in mixtures, identification of, 1467–77.
—— miscellaneous special tests for, 1476–7.
—— [fatty], mutual detection of, 1469–71.
—— removal of resinous matters from, 1460.
—— tables of full reactions of, 1472–5.
Okro (fibre), 961, (oil) 1397.
Oldenlandia umbellata (dye), 856.
Oldham willows (cotton manufactures), 739.
Oldfieldia africana (timber), 2018.
Olea capensis (oil), 1406.
—— europæa (oil), 1397–1406.
—— fragrans (tea), 2010.
—— undulata (timber), 2016.
Oleic acid (free), in an ordinary oil, estimation of, 1469.
—— stearic and palmitic acids, estimation of, 1463–4.
Oleine-tubes, 1463–6.
Oleography, 1604–6.
Oleomargarine, 1362–3.
—— analysis, 1464–6.
Oleo pardo (resin), 1678.
Oleo-resins, detection of, 1624–7.
—— nature, origin, &c., 1621–7.
Olibanum, 1623, 1627, 1676–7, (oil) 1425.
Olivenöl, 1397–1406.
Olive-fly, 1400.
Olive-oil, 1397–1406.
Oliver and Perret's kiln (sulphuric acid), 84, 86.
Omphalea spp. (nut), 1352, (oil) 1406.
Oolachan-oil, 1366.
Oomhlebe (timber), 2012.
Opal, 1042.
Opaque bdellium, 1637.
—— glass, 1083.
Opener for batting wool, 1102.
Opening cotton, 739.
Ophelia spp. (drug), 799, (spice), 1805.
Ophiocephalus striatus (oil), 1376.
Opium, 1308–24.
—— cultivation, distribution of, 1308.
—— imports, 1324.
—— in Asia Minor, 1309–11.
—— in China, 1317–22.
—— in Egypt, 1322.
—— in India, 1313–7.
—— in Persia, 1311–3.
—— nature, 1323–4.
Opium preparation, 1322–3.
—— production and commerce, 1308.
—— properties, 1323–4.
—— use, 1322–3.
—— values, 1324.
Opobalsamum, 1636.
Opochala oil, 1406.
Opodeldoc, 1792.
Opopanax, 1624, 1627, 1677.
—— bouquet, 1531.
—— spp. (resin), 1621, 1627, 1677.
Opossum fur, 1032.
Optical glass, 1082.
—— methods sugar analysis, 1956–64.
—— saccharometers, 1957–62.
Opuntia coccinilifera (dye), 856–7.
—— rubescens (resin), 1694.
—— spp. (resin), 1621.
Orange-flower extract, 1529.
—— —— oil, 1425.
—— —— water, 1425.
—— oil, 1425.
—— [Osage], oil, 1415.
—— soap, 1791.
—— spirit, 1302.
—— tree gums, 1677.
—— zeste, 1425.
Oranges (fruit), 1025–7.
Orcanète, 855.
Orchella, 864.
Ordeal-bean, 795.
Oreodaphne spp. (oil), 1422–3.
Oreodoxa spp. (oil), 1415.
Ores, valuation, 349.
Organic alkalies, 230.
—— impurities in fats, estimating, 1462.
—— matters in cane-juice, 1872–3.
—— —— in sugar, determination, 1947.
—— mordants, 1303.
Oriental elemi, 1677.
Origanum-oil, 1424, 1431.
—— spp. (oil), 1424.
Orkanet, 855.
Orlean, 855.
Ormer, 1517.
Ornamental feathers, 905.
—— glass, 1067.
Ornithogalum altissimum (drug), 826.
Ornus europæa (drug), 817–8.
Orpiment, 339.
Orris camphor, 578.
—— extract, 1529.
—— oil, 1425.
—— root, 1526–7.
Orthanthera viminea (fibre), 986.
Oruba Island phosphate, 1264.
Oryctes monoceros, 939.
Oryza sativa (arrack), 219–20, (starch), 1826–7.
Os, 521–5.
Osage orange (dye), 864, (oil) 1415.
Osiers, 995.
Osmerus sp. (oil), 1366.
Osmitopsis asteriscoides (oil), 1432.
Osmosis process (cane-sugar), 1880–3.
—— —— for extracting beet-juice, 1842–5.
—— —— for treating beet-molasses, 1858–9.
Osmogene for beet-molasses, 1858–9.
Ostrea edulis (pearl), 1517.
Ostrich-farming. 906–7.
—— grease, 1376.
—— plumes, 907.
Otaba wax, 2046.
Otaheite sugar-canes, 1860.
Otaria spp. (fur), 1032–3, (oil) 1375.
Otter fur, 1032.
—— sea, fur, 1032.
Otto's ammoniacal solutions table, 238.
Otto Pohl's salt-pans, 1737–9.
—— of roses, 1427–30.
Ouabe oil. 1406.
Ouaraye oil, 1414.
Ouatier as shade, 1815.
Ougeinia dalbergioides (resin), 1668.
Ouliépé resin, 1648.
Ounce-grease, 1376.
Ovens for distilling wood (acetic acid), 9–12, 15–19, 19–21.
Ovens for pottery, 1563–8.
—— tar, 1683.
—— see also burners and kilns.
Ovis moschatus (musk), 1525.
—— spp. (wool), 2053–6.
Owala oil, 1406.
Oxalates, 161, 173–4.
—— alumina, 1296.
—— potassium, 277.
—— tin, 1302.
Oxalic acid, 160–74.
—— —— by action of alkalies on neutral organic matters, 168–72.
—— —— by action of nitric acid on vegetable substances, 163–8.
—— —— concentrating, 173.
—— —— for sugar refining, 1929.
—— —— from guano, 161–3.
—— —— from madder, 172.
—— —— from other sources, 172.
—— —— from plants, 161.
—— —— from sugar, 163–4.
—— —— manufacture, 161–72.
—— —— occurrence, 160–1.
—— —— purification, 173.
—— —— recovery from dye-vats, 172.
—— —— value, 174.
Oxalis gigantea (tannin), 1993.
—— spp. (oxalic acid), 161, 173, 277.
Ox-hair, 1095, (hides) 1758.
Oxidizing oils, 1482.
Oxland and Hocking's calciner (arsenic), 336.
Oxyanthracene, 653.
Oxychloride lute, 630.
Oxygen in escaping gases (sulphuric acid), 71.
Oxymuriate antimony, 1296.
—— tin, 1303.
Oyster pearls, 1517.
Ozokerit, 589, 2046.

PACE'S machine for pointing match-splints, 1282–5.
—— splint-cutting machine, 1277–9.
Pachira aquatica (oil), 1415.
Pachyrrhizus angulatus (fibre), 986.
Pacific islands guano, 1259.
—— —— sugar-canes, 1861.
—— pearl fisheries, 1519–20.
Paco (fibre), 1093.
Pæderia fœtida (fibre), 919.
Pai-ch'ha wood, 2018.
Paint, 1552–6.
Painted glass, 1084.
Paints for glass, 1085.
—— indiarubber, 1158.
Palas kino, 1668, 1669, 1670, 1671.
Palissy ware, 1599.
Palm, collecting juice from (sugar), 1905–6.
—— cutting (sugar), 1905–6.
—— juice as beverage, 425–6.
—— boiling, 1906–7.
—— planting (sugar), 1904–5.
—— returns from (sugar), 1907–8.
—— sugar, 1904–8.
—— wax, 2046.
Palma Christi (oil), 1380–2.
Palmet (fibre). 994.
Palmetto (fibre), 938.
Palmitic, oleic, and stearic acids, estimation of, 1463–4.
Palm-kernel-oil, 1408.
Palm-nut, 1359.
—— —— kernel-oil, 1408.
—— oil, 583, 1406–8.
Palmöl, 1406–8.
Palmyra palm (fibre), 932.
Palo-de-vaca (resin), 1693.
Pampas grass, 920.
Panama crimson. 864.
—— pearls, 1520.
—— screw-pine (fibre), 938.
Panax Colensoi (resin), 1694.
—— spp. (drug), 811.
Pandanus spp. (fibre), 986.
—— utilis (for shade), 1815.
Pangium edule (oil), 1415.
Panicled acacia (fibre), 911.
Pan-scale, composition of, 1733.
Pans for concentrating cane-juice, 1890–2.
—— —— hydrochloric acid, 106–8.
Pans for salt-making, 1728–39.
Papaver Rhœas (dye), 864.
—— somniferum (alkaloid), 231, (drug) 820.
—— spp. (narcotic), 1308–24, (oil) 1409–10.
Paper, 1484–1509.
—— albumenized sensitive, 1540.
—— and paper materials, imports of, 1509.
—— bibliography, 1509.
—— cutting, 1503–5.
—— glazing, 1503.
—— hand-made, 1494.
—— industry, extent of, 1508–9.
—— machine, 1494–1500, 1502–3.
—— manufacture, 1486–1505.
—— materials, 1484–6.
—— mill, selection of site for, 1507–8.
—— mulberry (fibre), 933.
—— pulp, acetic acid from, 19.
—— soda recovery process, 1505–7, 1508.
—— statistics, 1508–9.
—— treatment of broke paper, 1494.
—— —— esparto, 1486–91.
—— —— rags, 1491–2.
—— —— straw, 1492.
—— —— wood, 1493–4.
—— tub-sizing, 1500–1.
—— varieties, 1507.
Paprika (spice), 1803.
Papyrograph, 1608–9.
Papyrus, 947.
Pará indiarubber, 1627.
—— nut, 1351–2.
—— piassava, 963.
—— rubber, 1661–4.
Paraffin, 586, 1509–16.
—— imports, 1516.
—— manufacture, 1510–4.
—— oil, 1446.
—— refining, 1514–6.
—— separator, 1515.
—— uses, 1516.
—— wax in fats, detection of, 1466.
Paranaphthalene, 650.
Parasaccharose, 1830.
Parcels of flax, 1214.
Parchment glue, 622.
Pareira-brava, 819.
Parfums, 1523–32.
Parian ware, 1558, 1596.
Parinarium sp. (oil), 1394, 1396.
Paris blue, 1548.
—— green, 669.
Parker's cement, 619.
Parkesine, 610–8.
Parkia biglandulosa (oil), 1415.
Parmelia spp. (oxalic acid), 161.
Parsley-oil, 1425.
Passalus tridens, 939.
Passiflora murucuja (narcotic), 1307.
Paste, ordinary, 622.
Pastilles, 1529–30.
Pastinaca sativa (oil), 1432.
Patawa (oil), 1386.
Patchouli camphor, 578.
—— extract, 1529.
—— oil, 1425.
—— satchet, 1531.
Pâte sur pâte, 1598.
Patent alum, 1295.
—— leather, 1236, 2032.
—— simplified still (alcohol), 205.
Patents, brewing-sugar, starch-sugar, and invert-sugar, 1938–40.
—— centrifugals, 1937–8.
—— evaporating apparatus, 1936–7.
—— filtration, 1937.
—— relating to sugar, 1936–42.
—— —— treatment of sugar-cane, 1936.
—— sundries (sugar), 1941–2.
—— vacuum-pans, 1936–7.
—— various chemical substances (sugar), 1940–1.
Patrinia scabiosæfolia (drug), 826.
Patrullo's machine (fibres), 916.
Patterson's beetling-machine (bleaching), 501.
Patwa (fibre), 921.
Paullinia spp. (guarana), 690–1.
Paulownia imperialis, (oil), 1415.
Paving-blocks from waste glass, 1087.
Pavot, 820.

Pawn (narcotic), 1305.
Pawtucket loom, 1102.
Payen's process of sugar analysis, 1947–8.
Pay-pay (tannin), 1993.
Pea-nut, 1357–8.
Pea (sweet), extract, 1529.
Peacock-grease, 1376.
Pear [alligator] oil, 1415.
Pear-wood, 2018–9.
Pearl, 1516–21.
—— artificial, 615, 1521.
—— bibliography, 1523.
—— buttons, 558.
—— mussel [Chinese], 1517.
—— qualities, values, and commerce, 1520–1.
Peat-oils, 1433.
Peau d'Espagne satchet, 1531.
Peaux, 1757–61.
Pebble copal, 1643.
Pech, 1678–80.
Pectinose, 1830.
Pederia fœtida (fibre), 919, 986.
Pedesis, 1793.
Pedilanthus spp. (resin), 1624.
Peepul (resin), 1668.
Peganum Harmala (narcotic), 1324.
Pegmatite, 1560, 1595.
Peinture, 1552–6.
Pekan fur, 1030.
Pekea ternatea (oil), 1415.
Pe-la wax, 2044.
Pelargonium spp. (oil), 1421.
Pellet's photographic printing process, 1617.
Pellicularia Koleroga (coffee), 698.
Pellitory, 819.
Pelotage of soap, 1790–1.
Pelotons, 1096.
Penang rubbers, 1656–7.
Penguin-oil, 1376.
Penicillium glaucum, 1829, 1830.
Penney's separator (coffee), 705.
Pennyroyal, 819, (oil) 1427.
Penœa spp. (resin), 1682.
Pentaclethra macrophylla (oil), 1406.
Pentadesma butyracea (oil), 1413.
Peonine, 680.
Pepper, 1812–4.
—— Ashantee, 1814.
—— betel, 1305.
—— black, 1812–4.
—— Cayenne, 1803.
—— Guinea, 1803.
—— intoxicating long, 1305, 1814.
—— Jamaica, 1814.
—— oil, 1425.
—— pod, 1803.
—— red, 1803.
—— West African, 1814.
—— white, 1814.
Peppermint, 819.
—— cordial, 227.
—— oil, 1425–7.
Pepper-pot (spice), 1828.
Perchloride of tin, 1302.
Percussion caps, 902.
Perfumed soaps, 1789–92.
Perfumers' pastilles, 1529.
Perfumery, bibliography, 1532.
—— imports, 1532.
—— values, 1532.
Perfumes, 1523–32.
—— crude, agar, 1523–4.
—— —— ambergris, 1524.
—— —— castor, 1524.
—— —— civet, 1524.
—— —— musk, 1524–6.
—— —— nagkassar, 1526.
—— —— orris, 1526–7.
—— —— sandal-wood, 1527–8.
—— —— tonquin-bean, 1528.
—— —— vanilla, 1528.
—— from plants, extracting, 1456–9.
—— prepared, 1528–32.
—— —— extracts or essences, 1528–9.
—— —— incenses and pastilles, 1529–30.
—— —— nosegays or bouquets, 1530–1.
—— —— satchets, 1531–2.
—— —— waters and eaux, 1532.
Perilla ocimoides (oil), 1415, 2045.
Périme vierge, 1686.
Periploca græca (resin), 1656.
—— indica (drug), 823.
Perkin's violet, 666.
Perle, 1516–21.
Permanent positive printing, 1540–1.
—— white, 1550.
Permuriate of iron, 1298.
Pernambuco rubber, 1627, 1664.
Perry, 421.
Per-salts of tin, 1302.
Persea gratissima (oil), 1415.
—— Lingue (tannin), 1994.
—— Nanmu (timber), 2018.
Persia, opium in, 1311–3.
—— tobacco in, 1337–8.
Persian ammoniacum, 1630.
—— berries, 864.
—— silk, 1747.
Persimmon wood, 2019.
Persoonia guareoides (oil), 1386.
Persulphate of iron, 1298.
Peru-balsam, 819, 1623, 1677–8.
—— —— black, 1625.
—— —— white, 1625.
Peruvian bark, 799–808.
—— guanos, 1258.
—— nutmeg, 1812.
Petabo (resin), 1657–8.
Petha wax, 2046.
Petit béraf, 1395.
—— grain-oil, 1427.
—— suif, 1361.
Petrel-oil, 1376.
Petrie's kiln (sulphuric acid), 57.
—— process (sulphuric acid), 100.
Petroleum, 1433–47, 2026.
—— constituents, separation and uses of, 1446–7.
—— origin and occurrence, 1433–41.
—— solidifying and liquefying, 1446.
—— spirit, extraction of oils, 1454–5.
—— storing, 1445–6.
—— testing, 1479–81.
—— transportation, 1443–5.
—— wells, boring and pumping, 1441–3.
Petromyzon fluviatilis (oil), 1376.
Peucedanum graveolens (drug), 810.
—— spp. (oil), 1432.
Peumus Boldus (drug), 794.
Pew's cement, 619.
Pewter, 324.
Pfeffer, 1812–4.
—— spanischer, 1803.
Pfefferminze, 819.
Phalæna saccharalis (cane disease), 1869.
Pheasant-grease, 1376.
Phenic acid, 41, 671–81.
Phenicienne, 681.
Phenol, 41, 671–81.
—— soap, 1789.
Phenyl-aniline, 658.
—— rosanilines, 664.
—— toluyl-amine, 658.
—— violets, 667.
Phenylic alcohol, 41, 671–81.
—— hydrate, 41, 671–81.
Philadelphus coronarius (oil), 1432.
Philippine elemi, 1649.
Phloiotribus oleæ, 1401.
Phoca spp. (oil), 1370.
Phocæna spp. (oil), 1369.
Phœnix dactylifera (fibre), 986, (fruit) 1024.
—— farinifera (starch), 1827.
—— sylvestris (sugar), 1904–8.
Phormium, baling, 992.
—— characters and uses, 992–3.
—— cultivation, 987–8.
—— exports and value, 993.
—— extraction, 988–92.
—— tenax (fibre), 986–93, (resin) 1678.
Phosphates, mineral, 1259.
—— —— alum from, 329–30.
—— natural, ammonium tri-phosphates from, 1851.
—— amount of acid required to dissolve, 1270.
—— [mineral], crushing, 1267.
—— —— grinding, 1268.
—— sodium, 316.
Phosphatic guanos, 1265.
Phosphoric acid in phosphates and superphosphates, 1265.
Phosphorite, 1261.
Photo-engraving processes, 1618–9.
Photographic applications, 1544.
—— instruments, 1532–6.
—— printing processes, 1616–20.
—— prints, toning, 1540.
—— processes, 1536–44.
Photography, 1532–44.
—— applications, 1544.
—— cameras, 1534–5.
—— camera-stands, 1536.
—— dark room, 1536.
—— diaphragms, 1533–4.
—— objectives, 1533.
—— processes, 1536–44.
—— studio, 1536.
Photo-lithography, 1617–8.
Photo-micrographic camera, 1535.
Photometry, 594, 1544–7.
Phthalic anhydride, 650, 682.
Phulwara-oil, 1408.
Phyllocladus tricomanoides (tannin), 1994.
Physeter macrocephalus (oil), 1371–2, (ambergris), 1524.
—— spp. (oil), 1361.
—— Tursio (oil), 1372.
Physic-nut, 1359, (oil) 1410.
Physostigma spp. (drug), 795.
Phytelephas spp. (buttons), 560, (nut), 1357.
Pia (starch), 1822.
Piassava, 920, 963.
Picea pectinata (timber), 2015.
Picked dog-fish (oil), 1370–1.
—— Turkey gum, 1631.
Picking esparto, 1486.
Picræna excelsa (drug), 820.
Picramic acid, 680.
Picrasma excelsa (drug), 820.
Picrates, 902.
—— ammonia, 680.
—— potash, 680.
—— soda, 680.
Picric acid, 40.
Pictet's ice-machine, 1140.
Pieces of flax, 1243.
Pieper's toughened glass, 1080.
Piéron's beetroot pulp press, 1839.
Piesse's pastilles, 1529–30.
—— posy bouquet, 1531.
Pig-hair, 1099.
Pig-nut-oil, 1392.
Pigeon-grease, 1376.
—— pea for green-soiling sugar-cane, 1866, 1869.
Pigments, 1548–52.
—— blues, 1548.
—— greens, 1548–9.
—— reds, 1549–50.
—— whites, 1550–1.
—— yellows, 1551–2.
—— for indiarubber manufactures, 1159.
Pikrinsäure, 40–1.
Pillow-lace, 1201.
Pilocarpus spp. (drug), 814.
Pilori (musk), 1525.
Pimelea spp. (fibre), 993.
Pimenta officinalis (oil), 1416, (spice) 1814.
Piment des Anglais, 1814.
—— —— Jardins, 1803.
Pimento, 1814, (oil) 1416.
Pimpinella Anisum (spice), 334–5, 1802–3.
—— spp. (oil), 1416–7.
Pin maritime, 1687–91.
Pine (acetic acid), 14–5.
—— gum, 1681.
—— oils, 1408, 1427.
—— wool, 993.
Pine-apple (fibre), 917, (fruit), 1027.
Pine marten fur, 1031.
Pines, 2019–20.
Piney resin, 1624, 1678.
—— tallow, 1408–9.
—— varnish, 1678.
Pinite, 1830.
Pinites succinifer (resin), 1628.
Pink (clove), extract, 1529.
—— salt, 1303.
Pinna squamosa (pearl), 1517.
Pinnay-oil, 1387–8.
Pinus Abies (resin), 1679–80.
—— Halepensis (resin), 1686.
—— spp. (drug), 818, (gunpowder) 884, (oil) 1408, 1427, 1431, (resin) 1624, 1683, 1684, 1686–92, (timber) 2019–20.
—— sylvestris (fibre), 993.
Pipe-clay, 640.
—— lines for petroleum, 1443–5.
Piper angustifolium (oil), 1424.
—— Betle (narcotic), 1305.
—— methysticum (drug), 815, (narcotic), 1305.
—— nigrum (oil), 1425.
—— Siriboa (narcotic), 1305.
—— spp. (drug), 809, 815, 818, (narcotic) 1305, (oil) 1420, 1424, 1425, 1427, (spice) 1812–4.
Pipli-múl (spice), 1814.
Pipturus spp. (fibre), 994.
Piquia-oil, 1409.
Piraracu-oil, 1376.
Pirria's process (sulphuric acid), 100.
Pirus Cydonia (drug), 820.
—— glabra (drug), 818.
Pispaz (resin), 1634.
Pissenlit, 826.
Pistachio-nut, 1359, (oil) 1409.
Pistacia Lentiscus (resin), 1673–4, (tannin) 1988.
—— spp. (nut), 1359, (oil) 1409, (resin) 1623, 1673–4, 1687.
—— vera (nut), 1359.
Pitch-tree (resin), 1649, (timber) 2016.
Pitcheri (narcotic), 1324.
Pitches, 1678–80.
Pitchouri (narcotic), 1324.
Pithecolobium dulce (oil), 1415.
Pittosporum spp. (resin), 1694.
—— undulatum (oil), 1432.
Pituri (narcotic), 1324.
Piver's absorption process for plant-odours, 1456.
—— saturator for impregnating grease with plant-odours, 1458–9.
Placuna spp. (pearl), 1517.
Plagianthus sidoides (fibre), 994.
Plane wood, 2020.
Planking hats, 1108.
Plantain-starch, 1823.
Plant-perfumes, extracting, 1456–9.
—— —— extracting by solvents, 1456–7.
Plants, oxalic acid from, 161.
—— potash from, 255–7.
—— [marine], potash chloride from, 263–5.
—— soda from, 280.
Platanus spp. (timber), 2020.
Plate-glass, 1057, 1059.
—— —— grinding, smoothing, and polishing, 1061–2.
—— —— Hartley's rolled, 1061.
—— sulphate, 278.
Plasters, 630.
Plates, pressing, 1578–9.
Platinotype printing, 1544.
Platinum retorts (sulphuric acid), 92–6.
Plectranthus crassifolius (oil), 1425.
Plisson's (M. D.) condenser (nitric acid), 157.
Plösslea floribunda (resin), 1677.
Plotting soap, 1790–1.
Plug tobacco, 1342.
Plumaria phagœdœnica (resin), 1665.
Plumbago, 1087.
Plumbers' cement, 626.
Plume nutmeg, 1812.
Plumes, 905.
Plum-oils, 1409.
—— spirit, 1302.
Plums, 1027.
Plusia gamma, 1835.
Poa spp. (fibre), 994.
Pochin's (H. D.) process (alum), 329.
Pod pepper, 1803.
Podocarpus cupressina (resin), 1694.
—— resin, 1625.
—— spp. (timber), 2017, 2019, 2021, 2022.
Podophyllum, 820.
—— peltatum (drug), 820, (dye) 856.

Poephagus grunniens (hair), 1099.
Pogada (resin), 1694.
Pogostemon Patchouly (oil), 1425.
Pohl's salt-pans, 1737–9.
Poinciana elata (resin), 1694.
—— regia (coffee shade), 714.
Point-lace, 1201.
Poire, 421.
Poitevin's powder, 1617.
Poivre, 1812–4.
—— de Guinée, 1803.
—— —— Inde, 1803.
—— —— la Jamaique, 1814.
Poix, 1678–80.
—— blanche, 1679–80.
—— —— factice, 1680.
—— de Bourgogne, 1679–80.
—— des Vosges, 1679.
—— jaune, 1679.
—— liquide, 1683.
—— noire, 1679.
Poizot et Druelle's beetroot pulp-press, 1839.
Polanisia viscosa (oil), 1415.
Polariscopes, 1957-62.
Polarized light, 1956–62.
Polecat fur, 1030.
—— (American) fur, 1033.
Polei, 819.
Polishing cotton, 765.
—— plate-glass, 1062.
—— rope and twine, 1701–3.
Polongo oil, 1415.
Polybia apicipennis (honey), 1128.
Polychrome print, 1604.
Polygala de Virginie, 824–5.
—— Senega (drug), 824–5.
—— tinctoria (dye), 858.
Polygonum amphibium (tannin) 1994.
—— cocciferum (dye), 861.
—— fagopyrum (starch), 1823.
—— spp. (dye), 858, 860.
Pomegranate gum, 1694.
Pomeæ (oil), 1416.
Pompelmousse, 1026.
Pongamia glabra (oil), 1393, (resin) 1694.
Pontifex's apparatus (citric acid), 50.
—— pan (cane-sugar), 1893.
—— process (tartaric acid), 175.
Pooa fibre, 932.
Poon wood, 2020.
Poondi-oil, 1393.
Poondy-oil, 1409.
Poongallee (resin), 1694.
Poon-seed-oil, 1387–8.
Pooree sugar-cane, 1860.
Poplar (acetic acid), 14, (oil) 1427, (timber) 2020.
Poppy (drug), 820, (dye) 864, (narcotic) 1308–24, (oil) 1409–10, 2023.
—— incisions in, for extracting opium), 1309, 1314, 1317.
Populus balsamifera (resin), 1683.
—— nigra (oil), 1427.
—— spp. (timber), 2020.
Porcelain, 1594-7.
—— analyses, 1558.
—— and glass cement, 628.
—— buttons, 559.
—— chasing, 1599.
—— colouring, 1599–1600.
—— English, 1596–7.
—— Parian and Belleek, 1596.
—— printing on, 1600–1.
—— Réaumur's, 1045–6.
—— Sèvres, 1594–6.
Porcupine (cotton manuf.), 740.
—— grass, 998.
Porgie-oil, 1368.
Porion's paper liquor evaporator, 1506–8.
Porous ware, 1596.
Porpoise-oil, 1369.
Portland cement, 619.
Portugal, eau de, 1532.
—— essence de, 1425.
—— satchet, 1531.
Possoz's process (oxalic acid), 169.
Pot-ashes, 253.
Potash, 250.
—— carbonate from beet molasses, 257–9.
—— —— —— brine springs, 259.
—— —— —— suint, 259–60.
Potash, carbonate from the sulphate, 260.
—— —— —— wine lees and tartars, 259.
—— caustic, 251–3.
—— —— densities, 251.
—— chloride from beet molasses, 266.
—— —— —— marine plants, 263–5.
—— —— —— potassic minerals, 262–3.
—— for soap-making, 1767–8.
—— in raw sugars, 1927.
—— isopurpurate, 680.
—— picrate, 680.
—— sources, 250–1.
Potass water, 367.
Potassic minerals, chloride potash from, 262.
Potassium acetate, 37.
—— bicarbonate, 260–1.
—— bichromate, 266.
—— bisulphate, 279.
—— bitartrate, 1303.
—— carbonate, 253–60.
—— —— from wood ashes, 255–7.
—— chlorate, 261.
—— chloride, 261.
—— —— from brine-springs, 265–6.
—— chromate, 266.
—— —— (yellow or neutral), 1297.
—— cyanide, 267.
—— dichromate, 1297.
—— ferri-cyanide, 267.
—— ferro-cyanide, 268.
—— hydrate, 251–3.
—— iodide, 273.
—— nitrate, 273.
—— oxalate, 277.
—— silicate, 276.
—— sulphate, 278.
—— tartrate, 279.
Potatoes, alcohol from, 211.
—— grating, 1824.
—— starch, 1823–6.
—— washing, 1823–4.
Poterie, 1556–1601.
Pot-grease, 1372.
Pot-pourri satchet, 1531.
Pottery, 1556–1601.
—— architectural and terra-cotta, 1582–7.
—— bibliography, 1601.
—— classification, 1568.
—— -clay, 610.
—— decorative processes, 1597–1601.
—— definition and general principles, 1556–8.
—— earthenware, 1573–82.
—— English china, 1596–7.
—— fireware, 1569–70.
—— kilns, ovens, and muffles, 1563–8.
—— manipulative processes, 1576–81.
—— porous ware, 1596.
—— raw materials, 1558–61.
—— stoneware, 1570–3.
—— tesselated and tile pavements, 1587–94.
—— terracotta and architectural, 1582–7.
—— throwing-wheels and lathes, 1561–3.
—— translucent wares, 1594–7.
—— wares, table of analyses, 1558.
Potton coprolites, 1260.
Pou à poche blanche, disease of sugar-cane, 1868–9.
—— blanc disease of sugar-cane, 1868–9.
Poudrette, 1271.
Pouliot vulgaire, 819.
Pounce, 1681.
Poupre, colour, 1300.
Pourretia spp. (resin), 1638.
Powdered soaps, 1792.
Prairie grass, 997.
Pratt's type-writer, 1606.
Preparing fabrics for curing, 1149.
—— flax, 1247.
—— must (wine), 435.
—— opium, 1322–3.
—— salts, 317, 1303.
Preservation [food], bibliography, 1022.
—— dairy produce, 1016.
—— fish, 1016–7.
—— fruit, grain, and vegetables, 1017–8.
—— meat, 1018–22.
—— wine, 441.
Pressed glass, 1078.
Presses (candles), 587, (gunpowder) 891–2, (indiarubber) 1156–7, (printing) 1602–3, (sugar) 1838–9, 1846, 1848–9.
Pressing hats, 1115.
—— pottery, 1578–9.
Prevention of nuisance. See Noxious vapours.
Price's apparatus (citric acid), 50.
—— phormium machine, 989.
Priestman's striking-machine, 1230–1.
Primula veris (tea), 2011.
Prinos glaber (tea), 2010.
Prinsepia utilis (oil), 1415.
Printer's oxymuriates of tin, 1303.
Printing and engraving, 1601–20.
—— bibliography, 1620.
—— in colours, 1604–6.
—— -inks, 1170.
—— linoleum, 1009–15.
—— on porcelain, 1600–1.
—— permanent positive, 1540–1.
—— presses, 1602–3.
—— processes (photographic), 1540, 1616–20.
Prints, double transfer, 1542.
—— single transfer, 1541–2.
—— (photographic) toning, 1540.
Prionium Palmita (fibre), 994.
Pristis spp. (oil), 1376.
Pro-argol, 1304.
Probirkunst, 346–60.
Procellaria glacialis (oil), 1375.
Proceras sacchariphagus (cane disease), 1869.
Proctor and Ryland's bone-boiler, 1450.
Procyon lotor (fur), 1032.
Proof for hats, 1111, 1127.
—— stick for vacuum-pan, 1857.
Proportion sulphur to chamber-space (sulphuric acid), 78.
Prosopis spicigera (resin), 1668, 1694.
—— spp. (resin), 1621, 1674, (tannin) 1982.
Prostanthera spp. (oil), 1432.
Pro-tartar, 1304.
Protomuriate tin, 1301.
Provencer Oel, 1397–1406.
Pruneæ (oil), 1416.
Prunes, 1027.
Prunus amygdalus (fruit), 1022.
—— gums, 1639.
—— serotina (oil), 1382–3.
—— spp. (fruit), 1027, (oil) 1409, (resin) 1621.
Prussian blue, 1548.
—— green, 1549.
Prussiate jaune de potasse, 268–73.
—— rouge de potasse, 267–8.
Psamma arenaria (fibre), 994.
Pseudococcus Adonidum (coffee), 699–700.
Pseudomeloë spp (drug), 797.
Psoralea glandulosa (tea), 2011.
Psychotria emetica (drug), 813.
Psylla oleæ, 1400.
Ptelea trifoliata (hops), 1131.
Pterocarpus angolensis (dye), 855, 856.
—— erinaceus (resin), 1668.
—— Marsupiam (resin), 1667–8.
—— spp. (dye), 857.
Pterocaulon polystachyum (drug), 794.
Pteropus edulis (oil), 1375.
Pteroxylon utile (timber), 2021.
Ptychotis spp. (drug), 791.
Pucha-pat (oil), 1425.
Pug-mill, 1576.
Pulping sugar-beets, 1837–8.
Pulu fibre, 939.
Pulvinaria gasteralpha (cane disease), 1868–9.
Pulza-oil, 1410.
Pumphrey's collograph, 1609.
Pumping oil-wells, 1441–3.
Pumpkin-oil, 1395.
Pumps, slip, 1675.
—— soap, 1778.
—— sugar juices, 1883–4.
Punica granatum (resin), 1694, (tannin) 1994.
Pupli, 864.
Pure for dressing-leather, 1232.
Purification, acetic acid. 19, 23.
—— carobiic acid, 675, 676.
—— coal-gas, 1035–40.
—— hydrchloric acid, 147.
—— oils and fats, 1459–62.
—— oxalic acid, 173.
Purple cotton spirit, 1303.
—— spirit, 1302.
Purpur, 1300.
Purqueira-oil, 1410.
Putorius spp. (fur), 1030, 1031–2.
Putranjiva Roxburghii (oil), 1415.
Putty, 630.
Puya spp. (resin), 1621, 1638.
P. Y. C. tallow, 1373.
Pycnocoma macrophylla (oil), 1379.
Pymma wood, 2020.
Pynkado wood, 2020.
Pyrene-oil, 1397–1406, 1454.
Pyrèthre salivaire, 819.
Pyrethrum-oil, 1427.
Pyrites (sulphuric acid), 80.
—— arsenical, 40.
—— estimating sulphur in, 87.
—— kilns (sulphuric acid), 80.
Pyroacetic spirit, 39.
Pyrogallic acid, 51.
Pyroligneous acid, 7.
Pyrolignite, 31–2.
—— iron, 1299.
Pyrophosphate of iron, 1300.
Pyrota spp. (drug), 797.
Pyroxylic spirit, 35.
Pyrus communis (timber), 2018–9.

QUASSIA, 820.
Quebrachia Lorentzii (tannin), 1988.
Quebracho, 1988.
—— colorado (resin), 1680.
Queensland hemp, 996.
—— pearl fisheries, 1518–9.
Quercite, 1830.
Quercitron, 864.
Quercus coccifera (dye), 861.
—— robur (oil), 1415.
—— sessiliflora (tannin), 1982.
—— spp. (cork), 723, (drug), 818, (dye) 864–5, (gunpowder) 884, (tannin), 1983–4, 1987–8, 1992–3, (timber) 2018.
—— suber (cork), 722–9.
Quetschen, 1027.
Quick vinegar process, 7, 2041–2.
Quills, 908.
Quince, 820.
Quinine, 231.
Quinizarine, 682.
Quinoa (narcotic), 1308.
Quitte, 820.

RABBETH spindle (cotton manufacture), 762.
Rabbit fur, 1032.
Raccoon fur, 1032.
Racine d'Iris, 1526–7.
Rack, 219.
Racking (wine), 438.
Radish-oil, 1415.
Radisson's process (candles), 584.
Raffinage du sucre, 1921–35.
Rags, bleaching, 1492.
—— boiling, 1491–2.
—— cutting, 1491.
—— dusting, 1491.
—— for paper, 1484–5.
—— treatment of for paper-making, 1491–2.
Railway-grease, 1797–8.
Rain-water, composition of, 151.
Raisins, 1027.
Raja spp. (oil), 1376.
Raki (spirit), 1673.
Rameta bast, 963.
Ramie fibre, 921.
Ram-til oil, 1396.
Rancidity in fats, correction of, 1461.

Raugoon rubbers, 1656–7.
Rape-oil, 1384–5.
Raphanus sativus (oil), 1415.
Raphia Hookeri (nut), 1357.
—— spp (fibre), 994.
—— tædigera (oil), 1392.
Raposa-grease, 1376.
Rapsöl, 1384–5.
Rare, 1686.
Rasping sugar-beets, 1837–8.
Rata wood, 2020.
Ratadel (resin), 1693.
Ratafia, 227.
Ratanhia, 820.
Ratooning sugar-canes, 1868.
Rats as enemies to sugar-cane, 1868.
Ravenala spp. (oil), 1433.
Raw copal, 1641.
Ray-oils, 1364, 1376.
Reactions of all the usual oils, tables of, 1472–5
Realgar, 340.
Rebicek's cane-slicer, 1881.
Receptacles for petroleum, 1445–6.
Recovery of waste grease, 605–6, 1455–6.
Rectification acetic acid, 19, 23.
—— alcohol, 212–3.
—— benzol, 647–8.
—— naphtha, 646.
Rectifying column (alcohol), 199.
Red chalk, 1550.
—— chromate, 1297.
—— chrome, 1297.
—— coralline, 680.
—— cotton spirit, 1303.
—— lead, 1550.
—— —— lute, 631.
—— liquor, 28–9, 1295–6.
—— mottled soap, 1787–8.
—— pepper, 1803.
—— pigments, 1549–50.
Red River snake-root, 825.
Red Sea pearls, 1517.
Red sulphate, 1298.
Reddle, 1550.
Redonda phosphate, 1264.
Reece's process (ammonia), 237.
Reeling cotton, 764.
—— flax, 1253.
—— silk, 1753–4.
Refined alkali, 302.
Refining borax, 539–40.
—— camphor, 575–6.
—— glucose, 1917–8.
—— oils and fats, 1459–62.
—— paraffin, 1514–6.
—— saltpetre, 884.
—— soda, 302–3.
—— sugar, 1921–35.
—— sulphur, 884–6.
—— sulphuric acid. 92–6.
Refraction of nitrates, 277.
Refrigerating machines, 673, 1019–20, 1135–41.
Refrigeration, artificial, 673, 1019–20, 1134–42.
—— bibliography, 1142.
—— by ammonia, 237.
—— cane-juice, 1900.
—— carbolic acid, 673–4.
Réglisse, 816–7.
Reichenbach's apparatus (acetic acid), 20.
Reine d'Angleterre bouquet, 1531.
Reisstärke, 1826–7.
Relargage of hard soap, 1779.
Relief printing processes, 1618–9.
Remington type-writer, 1608.
Rendering animal fats, 1417–51.
Rendrock, 901.
Reseda luteola (dye), 868, (oil) 1415.
—— odorata (oil), 1424.
Resins, combination with oil (varnish), 2034–5.
—— detection of, 1624–7.
—— for varnish, 2024–5.
—— fusion, 2033.
—— nature, origin, &c., 1621–7.
—— preparation (varnish), 2033.
Résineuses et gommeuses, matières, 1620–95.
Resinous and gummy substances, 1620–95.
—— amber, 1628–30.
—— ammoniacum, 1630.
Resinous and gummy substances, arabic, 1630–3.
—— asafœtida, 1633–5.
—— balata, 1635–6.
—— balm of Gilead, 1636.
—— bdellium, 1636–7.
—— benzoin, 1637–8.
—— bibliography, 1695.
—— cadjii, 1638.
—— chagual, 1638.
—— cherry, 1638–9.
—— chicle, 1639.
—— chironji, 1639.
—— coconut, 1639.
—— copaiba, 1639–40.
—— copal and animi, 1640–4.
—— dammar, 1644–5.
—— dextrine, 1645–7.
—— dhoura, 1647–8.
—— dika-mali, 1648.
—— dragon's blood, 1648–9.
—— elemi, 1649.
—— euphorbium, 1649.
—— frankincense, 1649–50.
—— galbanum, 1650.
—— gamboge, 1650–1.
—— ging and kunnee, 1651.
—— guaiacum, 1651.
—— gurjun, 1651–2.
—— guttapercha, 1652–4.
—— guttashea, 1654.
—— hardwickia, 1654.
—— hog, 1654.
—— indiarubber, 1654–66.
—— jumrasi, 1666.
—— jutahy-seca, 1666.
—— kauri, 1666–7.
—— kino, 1667–8.
—— kos, 1668.
—— lac, 1668–73.
—— mahogany, 1673.
—— mango, 1673.
—— mastic, 1673–4.
—— mezquite, 1674.
—— miscellaneous, 1693–5.
—— mochurrus, 1674.
—— moringa, 1674.
—— myrrh, 1674–5.
—— nagdana, 1675.
—— olibanum, 1676–7.
—— opopanax, 1677.
—— orange, 1677.
—— Peru balsam, 1677–8.
—— phormium, 1678.
—— piney, 1678.
—— pitches, 1678–80.
—— retinite, 1680.
—— rimu, 1680.
—— rosin and rosin-oil, 1680–1.
—— sagapenum, 1681.
—— sandarach, 1681–2.
—— sarcocolla, 1682.
—— satin-wood, 1682.
—— schaufite, 1682.
—— storax, 1682–3.
—— tamanu, 1683.
—— tars, 1683–4.
—— tendoo and gaup, 1684.
—— thus, 1684.
—— tolu, 1684–5.
—— tragacanth, 1685–6.
—— turpentine, 1686–92.
—— varnishes, 1692.
—— wood-apple, 1692–3.
—— xanthorrhœa, 1693.
Resinous matters, removal of from oils, 1460.
Resorcine, 682.
—— phthaline, 682.
Retenage of leather, 1234.
Retinite, 1680.
Retinodendron lanceæfolia (resin), 1678.
Retorts, ammonia, 240–1.
—— ferrocyanide potassium, 269, 271, 272.
—— for refining sulphur, 885.
—— —— wood distilling (acetic acid), 9–12, 15–19, 19–21.
—— hydrochloric acid, 104–9.
—— nitric acid, 155–8.
—— oxalic acid, 164–6.
—— paraffin, 1511.
—— sulphuric acid, 92–6.
—— wood charcoal, 883.
Retouching negatives, 1530–40.
Retting, 967.
Revivifying animal charcoal, 1853–4, 1923–6.
Revolving ball-furnace (soda), 292.
—— flat card (cotton manuf.), 747.
Reworking indiarubber compounds, 1161.
Rhamnus cathartica (drug), 795.
—— Frangula (gunpowder), 882–4, (timber) 2015.
—— spp. (dye), 855, 864, (tea) 2010.
Rhapis flabelliformis (cane), 597.
Rhatany, 820.
Rhea plumes, 908.
—— spp. (feathers), 908.
Rheea fibre, 921.
Rheum spp. (drug), 820–2.
—— vulgare (oxalate potash), 277.
Rhigolene, 1446.
Rhizophora Mangle (tannin), 1994.
Rhodium-oil, 1430.
Rhododendron spp. (narcotic), 1324, (tea) 2010.
Rhubarb, 820.
—— (oxalate potash), 277.
Rhus Metopium (resin), 1621.
—— spp. (resin), 1623, 1692, (tannin) 1984, 1988–92, (wax) 2045.
Rhyncobatus spp. (oil), 1367.
Rhyncophorus spp. (cane disease), 1869.
Rib-top frame, 1194.
Rice-starch, 1826–7.
Richardia spp. (drug), 813.
Richardsonia spp. (drug), 813.
Ricinus communis (shade), 716, (drug) 798.
Ricinussamenöl, 1380–2.
Ricinus spp. (oil), 1380–2.
Rigaud and Dussart's flower-still, 1458.
Rigg's chromo-litho process, 1606.
Righter for upper leathers, 1234.
Rilleux's begass furnace, 1877.
—— triple-effect vacuum - pan, 1897–8.
Rimu, 1680.
Ring frame (cotton manuf.), 761.
Ripe copal, 1641.
River pearls, 1517.
Roach alum, 1295.
Roberts, Dale, & Co.'s processes (oxalic acid), 169, 170, 172, 173.
Robert's diffusion process for beet, 1843–4.
—— —— —— for cane, 1881–3.
—— lightning-proof oil-tank, 1445.
Robinia pseudo-acacia (timber), 2012.
Robinson and Andrews' twist-tobacco machine, 1342–5.
Roble colorado (tannin), 1994.
Rocella spp. (dye), 862, 864.
Rochelle salts, 190, 279.
Rock-alum, 1295.
—— dammar, 1645.
—— guanos, 1264.
—— oil, 1433–47.
—— salt, 1719–24.
—— —— composition of, 1724.
—— —— mining, 1723–4.
—— —— working, 1725.
Rocou, 855.
Roeckner's paper liquor evaporator, 1506.
Roessel's machine (fibres), 926.
Rohr, 595–8.
Röhrencassle, 798.
Rohrzucker, 1860–1902.
Rohun wood, 2020.
Roi bouquet, 1531.
Roka oil, 1415.
Roland's machine (fibres), 927.
Rolled plate-glass, 1061.
Roller card (cotton manuf.), 744.
Roll tobacco, 1342–4.
Roman cement, 620.
—— vitriol, 1297.
Rondeletia bouquet, 1531.
Roofing-tiles, 1572–3.
Rope, 1695–1710.
—— factories, 1697.
—— for paper, 1485.
—— walks, 1696.
Ropes, 1704–10.
Rosa spp. (oil), 1427–30.
Rosaniline, 660.
Rosbach water, 364.
Rose extracts, 1529.
Rosemary-oils, 1430.
—— wild (narcotic), 1308, (oil) 1430.
Rosenöl, 1427–30.
Rose-oil, 1427–30.
—— otto, 1427–30.
—— satchet, 1531.
—— soap, 1790, 1792.
—— water, 1427–30.
Rosewood, 2020, (oil) 1430.
Rosin, 1624, 1625, 1680–1, 2024.
—— for soap-making, 1767.
—— oil, 1681, 2026.
—— —— in mixed oils, estimation of, 1467–9.
Rosmarinus officinalis (oil), 1430.
Rosmarus obesus (ivory), 1175, (oil) 1374.
Rosolic acid, 680.
Rössling and Reichardt's method (starch-sugar), 1919.
Rotatory power of sugars, 1962.
Rottlera tinctoria (dye), 861, (oil) 1415.
Rothesblutlangensalz, 267–8.
Rothes Schwefelarsenik, 340.
Roughing flax, 1243.
—— glass, 1074.
—— hats, 1120.
Round cardamom, 1804.
Roussa grass (fibre), 919.
Rousselot's 3-roller cane-mill, 1873–4.
Roussilon's photo-engraving process, 1619.
Roving cotton, 752.
—— frame for flax, 1249–51.
—— jute, 1181.
Royal Hunt bouquet, 1531.
Rubber stamp, inks for, 1172.
Rubbing machine (bleaching), 516.
Rübenzucker, 1831–60.
Rubia spp. (dye), 862–3, 863–4.
—— tinctoria (oxalic acid), 172.
Ruby, 1043.
Rue, Syrian or Steppe (narcotic), 1324.
—— oil, 1430.
Ruelle revivifying kiln, 1853–4.
Ruellia indigotica (dye), 858.
Rum, 228.
Rumex spp. (oxalic acid), 161, 277.
Russia leather, 1236.
—— phosphates, 1264.
Rust on sugar-cane, 1869–70.
Ruta graveolens (oil), 1430.

SABADILLA officinarum (drug), 798.
Sabadillsamen, 798.
Sabal Palmetto (fibre), 994.
Sabicu wood, 2020.
Sable fur, 1031.
—— Russian (fur), 1031.
Sabzi (narcotic), 1306.
Saccharine solutions, alum from, 330.
—— substances, Clerget's tables, 1949–51.
Saccharometers, optical, 1957–62.
Saccharometry, 1942–71.
Saccharose, 1830.
Saccharum officinarum (sugar), 1860.
—— spp. (fibre), 994.
Sack tree (fibre), 919.
Sacqui (fibre), 916.
Saddening-irons, 1299.
Safflower, 865, (oil) 1410.
Saffron, 866, (oil) 1430.
Safranine, 662.
Sagapenum, 1624, 1626, 1681, (oil) 1430.
Sage-oil, 1430.
Sageretia theezans (tea), 2011.
Saggers, 1569–70.
Sago, 1827–8.
Saguerus Rumphii (fibre), 919.
—— saccharifera (starch), 1827, sugar (1904).
Sagus amaricum (nut), 1357.
—— spp. (fibre), 994.
—— tædigera (oil), 1392.

Saindoux, 1366–7.
St. Ignatius' bean, 231, 822.
—— **Martin's Island phosphate, 1264.**
Salabreda gum, 1631.
Salad-oil, 1406.
Salangore sugar-cane, **1861.**
Sal dammar, 1644.
Salicornia sp. (oxalic acid), 161, (soda) 280.
Salicylic acid, 681.
Salisburia adiantifolia (nut), 1357.
Salix alba (gunpowder), 882–4.
—— **fragilis (drug),** 818.
—— spp. (fibre), 995, (timber) 2022.
Salmalia malabarica (resin), 1674.
Salmon-oil, 1376.
Salpetersäure, 148–60.
Salpetersäures kali, 273–7.
Salsola spp. (oxalic acid), 161, (soda) 280.
Salt, 1710–40.
—— bay-, 1714–9, 1732–3.
—— boiled, 1732.
—— (rock-), composition of, 1724.
—— (sea-), composition of, 1718.
—— (white), composition of, 1735.
—— cake, 317–8.
—— —— making, 280–9.
—— cost of, 461.
—— fine, 1732.
—— fishery-, 1732–3.
—— for soap-making, 1769.
—— gardens, 1716.
—— glazing, 1572.
—— maker's tools, 1717.
—— making by freezing, 1718.
—— manufacture, profits of, 1739–40.
—— marshes, 1716.
—— nomenclature of, 1728.
—— of lemon, 277.
—— of saturn, 32.
—— of tin, 1301.
—— "preparing," 317.
—— origin and occurrence of, 1711–14.
—— pans, 1728–39.
—— scale, composition of, 1733.
—— sea-, 1714–9.
—— solubility of, in water, 1711.
—— solutions, specific gravities of, 1711.
—— stoves, 1731.
—— unboiled, 1732–3.
—— white, 1724–40.
—— works, ideal arrangement, 1739.
Salterns, 1714–6.
Saltpetre, 273.
—— refining (gunpowder), 884.
Saltpond oil, 1407.
Salvia Chio (oil), 1415.
—— officinalis (oil), 1430.
Salvadora sp. (oil), 1392.
Sal wood, 2020.
Salz, 1710–40.
Salzburg vitriol, 1297.
Salzgärten, 1716.
Samadera indica (drug), 820.
Samara Ribes (spice), 1814.
Sambucus nigra (oil), 1420.
Samming leather, 1237.
Sanani gum, 1654.
Sandal-wood, 1527–8.
—— —— extract, 1529.
—— —— oil, 1430.
Sandarach, 1624, 1625, 1681–2, 2024.
Sandaraque, 1681–2.
Sandarus (resin), 1641.
Sandarusiza miti (resin), 1641.
Sandelholz, 1527–8.
Sanders-wood, 867.
Sandpapering hats, 1116.
Sandre-oil, 1376.
Sand soap, 1789.
Sandford & Mallory machine (fibres), 917.
Sang dragon, 1648–9.
Sangue del drago, 1668.
Sanseviera zeylanica (fibre), 995.
Santa Fé nutmeg, 1812.
Santal citrin, bois de, 1527–8.
Santalum spp. (oil), 1120, (perfume) 1527–8.
Sapan-wood, 867.
Sap **green, 1549.**
Sapindus spp. (oil), 1360, 1411, (resin) 1694.
Sapinette, 424–5.
Sapium scoparium (resin), 1665.
—— sebifera oil, 1412.
Saponaria officinalis (oil), 1446.
Saponification, 579–82, 583–6, 1764–5.
Sapota, 1635, 1639.
—— Mülleri (resin), 1635–6, 1639.
Sapphire, 1043.
Sapucaya-nut, 1359, (oil) 1414.
Sarcocolla, 1682.
Sarcostigma Kleinii (oil), 1397.
Sardine-oil, 1369–70.
Sarothamnus vulgaris (drug), 795.
Sarsaparilla, 822.
Sassafras, 823.
—— camphor, 578.
—— officinalis (drug), 823.
—— oils, 1430–1, 1640.
Sassa gummifera (resin), 1632.
Sassy, 823.
Satchets, 1531–2.
Satin-wood, 2021, (gum) 1682.
Sauerkleesäure, 160–74.
Saul wood, 2020.
Säure, 1.
Säures weinsäures kali, 279.
Savakin gum, 1631–2.
Savin-oil, 1419, 1431.
—— [American] (oil), 1419.
Savon, 1764–97.
Sawdust as source of acetic acid, 15–19.
—— oxalic acid from, 169–72.
Saw-fish oils, 1376.
Saxon blue, 1548.
Scammony, 823, (resin) 1624.
Scamoni's photo-engraving process, 1618.
Scarabæus auratus (drug), 796.
Scarification, extracting essential oils by, 1457.
Scarlet finishing-spirit, 1302.
—— spirit, 1302.
Scented soaps, 1789–92.
Schabzieger cheese, 1528.
Schaffner's process (soda), 312.
Schaufite, 1682.
Scheele's green, 1549.
Scheibler's elution process for beet-molasses, 1859–60.
Scheidewasser, 148–60.
Schiffspech, 1679.
Schinz's apparatus (potassium ferrocyanide), 271.
Schlafmittel, 1305–21.
Schlangenwurzel, 825.
Schleichera trijuga (oil), 1415, (resin) 1668.
Schmack, 1988–92.
Schmalz, 1366–7.
Schmersohl & Bouk's process (sulphuric acid), 100.
Schnaps, 222.
Schnellerkäse, 794.
Schneider & Laming's process (sulphuric acid), 100.
Schœnacaulon officinale (drug), 798.
Schottensand, 1903–4.
Schreiber's charcoal-washer, 1852–3.
—— revivifying kiln, 1853.
Schrœder's pan (cane-sugar), 1892.
Schultz's powder, 897.
Schusterpech, 1679.
Schutzenbach's maceration system (beet-juice), 1839–40.
Schwamm, 1817–21.
Schwartz's apparatus (acetic acid), 20.
Schwarzes pech, 1679.
Schwefelkohlenstoff, 601–8.
Schwefelsäure, 51–101.
Schwefelsäures baryt, 361–2.
—— kali, 278–9.
—— natron, 317–8.
Schweinfurth green, 1549.
Scilla spp. (drug), 825–6.
Scille, 825–6.
Scirpus lacustris (fibre), 996.
Scopolia japonica (drug), 794.
Scorodosma fœtida (resin), 1624.
Scotch pearls, 1517.
Scrape, 1684, 1688.
Scraping machine (fibres), 913.
Screening artificial manures, 1271.
Screw-pine (fibre), 986.
Scrophularia frigida (drug), 818.
Scouring-machine (leather), 1235.
Scrubbers for destroying noxious vapours, 1273.
Scrubbing coal-gas, 241.
Scudding leather, 1232.
Scutch as manure, 1266.
Scutching cotton, 741.
—— flax, 973.
Scymnus spp. (oil), 1370–1.
Sea-hog-oil, 1365.
—— -horse-oil, 1374.
—— -otter fur, 1032.
—— -salt, 1714–9.
—— —— composition of, 1718
—— -water, chloride potassium from, 265–6.
—— —— composition of, 1715.
—— -wolf-oil, 1376.
Seal fur, 1032, (oil) 1370, (skins) 1758.
Sebastian, 901.
Seed-oils, 1410.
—— —— extraction, 1451–5.
Seehundsöl, 1370.
Seesum wood, 2021.
Seide, 1741–8.
Seidelbast, 818–9.
Seidengewerbe, 1748–56.
Seidlia lanceæfolia (resin), 1678.
Seidlitz water, 367.
Seife, 1764–97.
Seigle ergoté, 810.
Sel, 1710–40.
—— de Saturne, 32–4.
—— gemme, 1719–24.
—— marin, 1714–9.
Selache maximus (oil), 1370–1.
Self-fastening buttons, 569.
Seltzer water, 364.
Semecarpus Anacardium (ink), 1169.
—— spp. (resin), 1692.
Semences de Carvi, 1803.
Semencine, 826–7.
Semen-contra, 826–7.
Senega, 824.
Senegal gum, 1621, 1631.
Senf, 1810.
Senna, 825.
Sennar gum, 1631.
Sensitive paper, albumenized, 1540.
Sensitizing carbon-tissue, 1541.
Separator for paraffin, 1515.
Sequa oil, 1414.
Seraglio pastilles, 1530.
Serapit (resin), 1657.
Serbat lute, 631.
Sericiculture, 1741–8.
Sericographis Mohitl (dye), 863.
Sernamby rubber, 1662.
Serpentaire, 825.
Serpentary, 825.
Sesame-oil, 1388–90.
Sesamöl, 1388–90.
Sesamum spp. (oil), 1388–90.
Sesbania aculeata (fibre), 996.
Sesquioxide of chrome, 1296.
Sethia indica (resin), 1684.
Sèvres porcelain, 1594–6.
Sewing silk, 1755.
Sewings, 1763.
Seyferth's elution process for beet molasses, 1859–60.
Shaddock, 1026.
Shajar el sandarus (resin), 1641.
Shale-oils, 1433, 2032.
Shanks' apparatus (soda), 296.
Shaping hats, 1117.
—— silk hats, 1126.
Shark-oil, 1364, 1370–1.
Shaved hides, tannage of, 1232–3.
Shaving soaps, 1792.
Shawl goat-hair, 1097.
Shea-butter, 1410.
Shed, treatment of sole-leather in, 1231.
Sheep-skins, 1758–9.
—— varieties (wool), 2053–6.
Sheet-glass, 1057.
—— —— blowing, 1066.
—— —— manufacture, 1063.
—— —— spreading and annealing kiln, 1066.
Sheet rubber, 1145.
Shellac, 1668–73.
—— ground, 1671.
Shell-bark oil, **1392.**
Shimptee **gum, 1651.**
Shier's process **for defecating cane-juice, 1887.**
Shir (resin), 1634.
Shirt-buttons, 559.
Shoddy, 2037–8.
—— as manure, 1266.
Shorea robusta (timber), 2020–1.
—— spp. (resin), 1624, 1644, 1668.
Shorts of flax, 1244.
Shumac, 1988–92.
Siam benzoin, 1637–8.
Siberian fungus, 1324.
Sida canariensis (tea), 2011.
—— spp. (fibre), 911, 996.
Siddhi (narcotic), 1306.
Sideroxylon attenuatum (resin), 1627, 1652.
—— spinosum (oil), 1377–8.
—— spp. (resin), 1665.
Siemens' gas furnaces for pottery, 1565–8.
—— regenerative gas furnace, 1053.
—— sieve (starch), 1824.
Sieves (starch), 1824–5.
Sifting-machines (starch), 1824–5.
Sight-glass for vacuum-pan, 1857.
Silica as a mordant, 1300.
Silicate potassium, 277.
—— sodium, 316.
Silicated soaps, 1786–8.
Silicoborocalcite, 527.
Silk, 1741–8.
—— bleaching, 518.
—— —— and scouring woven silk, 520.
—— —— silk yarn, 518–9.
—— cleaning, 1750–1.
—— cotton, 932.
—— deniering, 1753–4.
—— dramming, 1753–4.
—— dyeing, 1754.
—— grass, 985.
—— hard, 1754.
—— hats, 1121.
—— manufactures, 1748–56.
—— noil, 1755.
—— oiled, 2032.
—— production and commerce, 1741–7.
—— raising, 1741.
—— reeling, 1753–4.
—— sewing, 1755.
—— sizing, 1754.
—— soft, 1754.
—— spinning and doubling, 1751–3.
—— spun, 1754–6.
—— thrown, 1754.
—— vegetable, 939.
—— waste, 1754–6.
—— weaving, 1756.
—— weed, 920.
—— winding, 1749–50.
—— woven, scouring and bleaching, 520.
—— yarn, 1755.
—— —— bleaching and tinting, 519–20.
—— —— —— scouring with acids, 519.
—— —— —— scouring with alkaline carbonates, 519.
—— —— —— scouring with caustic alkalies, 519.
—— —— —— scouring with soap, 519.
—— —— sulphuring, 519.
—— —— twisting, 519–20.
Silkworm-gut, 610, (oil) 1376.
Silpha opaca, 1835.
Silurus spp. (oil), 1376.
Silver amalgam, 334.
—— assay, 356.
—— cloth, 920.
—— detection, 349.
—— Y moth, 1835.
Silvering, 877.
Simaruba spp. (drug), 820.
Simbolee-oil, 1410.
Simiri (resin), 1666.
Simli gum, 1694.

Sinapis spp. (oil), 1396, 1424, (spice) 1810.
Sinclair's esparto boiler, 1487.
Singapore dammar, 1644.
Singeing rope and twine, 1701.
Singhara-nut, 1359.
Single aquafortis, 1302.
—— flax, 1249.
—— muriate of tin, 1301.
—— transfer prints, 1541–2.
Siphocampylus sp. (resin), 1628.
Siphonia elastica (oil), 1411.
—— spp. (rubber), 1627, 1661–4.
Siringa-oil, 1411.
Siris (resin), 1632.
Sisal hemp, 916.
Sison Amomum (drug), 791.
Sissu wood, 2021.
Site for paper-mill, selection of, 1507–8.
Size, 622.
Sizing cotton, 766, 770.
—— esparto, 1489–90.
—— jute, 1185.
—— machines (cotton manuf.), 773.
—— [tub-] paper, 1500–1.
—— silk, 1754.
—— twine and rope, 1701–3.
Skimi (spice), 1802–3.
Skin, anatomical structure, 1213.
—— chemical composition, 1217.
Skins, 1757–61.
Skoda's press for drying exhausted beet-slices for cattle-food, 1846.
Skunk fur, 1033.
Slag from blast-furnace for glass, 1076.
Sleeker for leather, 1234.
Slicing-machines for beet, 1843.
—— —— for sugar-cane, 1880, 1881.
Slide for vacuum-pan, 1857.
Sligovitch, 1027.
Slip pump, 1575.
Slubbing cotton, 751.
Smallwares, 1761–4.
Smilax glyciphylla (tea), 2010.
—— spp. (drug), 799, 822–3.
Smith's guttapercha cores, 1163.
Smoking-tobacco, preparation, 1340–2.
Smoothing plate glass, 1062.
Smut on sugar-cane, 1870.
Snake-root, 825.
Sneezewood, 2021.
Soaking hides, 1219.
Soap, 1764–97.
—— action of, 1792–4.
—— analysis, 1792–6.
—— antiseptic, 1789.
—— bibliography, 1802.
—— boiled in open pans, 1777–9.
—— —— under pressure, 1773–4.
—— brown almond, 1789.
—— —— Windsor, 1789–90.
—— carbolic acid, 1789.
—— cold process, 1771–3.
—— —— water, 1789.
—— coloured, 1791.
—— commerce, 1797.
—— coppers, 1774–5.
—— —— emptying, 1781.
—— crutching, 1785–6.
—— curd, 1779.
—— curing, 1783.
—— cutting, 1781–3.
—— disinfecting, 1789.
—— drying, 1783.
—— elder-flower, 1791.
—— essences, 1792.
—— exports, 1797.
—— fan, 1775–6.
—— fig, 1776–7.
—— filled, 1785–8.
—— fitting, 1780.
—— floating, 1792.
—— frames, 1781.
—— from fatty acids, 1771.
—— —— neutral fats, 1771–4.
—— glycerine, 1789, 1792,
—— hard, 1777–9.
—— —— clear-boiling, 1779.
—— —— separation, 1779.
—— honey, 1789, 1792.
—— household, 1789.
—— hydrated, 1777.
—— industry, 1796–7.
Soap, laundry, 1789.
—— lemon, 1791.
—— leys, 1800.
—— manufacture, 1770–92.
—— manufacturers', 1788–9.
—— marsh-mallow, 1790.
—— millefleur, 1791.
—— mixing, 1785–6.
—— mottled, 1780.
—— —— blue-, grey-, and red-, 1787–8.
—— moulding, 1783–4.
—— neat, 1770–84.
—— nut, 1360, (oil) 1411.
—— orange, 1791.
—— pans, 1771–5
—— perfumed, 1789–92.
—— plotting, 1790–1.
—— powdered, 1792.
—— pumps, 1778.
—— railway-grease and glycerine, 1764–1802.
—— raw materials, 1766–9.
—— rose, 1790, 1792.
—— sand, 1789.
—— scented, 1789–92.
—— shaving, 1792.
—— silicated, 1786–8.
—— soft, 1774–7.
—— stamping, 1783–4.
—— steam-twirl, 1771–3.
—— suds, recovery of grease from, 1455–6.
—— thymol, 1789.
—— toilet, 1789–2.
—— transparent, 1792.
—— valuation, 1792–6.
—— violet, 1792.
—— yellow, 1780–1.
Soaps as mordants, 1305.
Socotran dragon's-blood, 1648.
Soda, 279.
—— aluminate, 1787.
—— ammonia soda, 311–2.
—— ball soda, 289–95.
—— basis of sale, 301.
—— black ash, 289–95.
—— boiling down soda liquors, 298–9.
—— carbonate, manufacture, 280–302.
—— carbonating black ash, 299–301.
—— caustic soda, 305–10.
—— crystals, 303–5.
—— for soap-making, 1767–8.
—— from plants, 280.
—— hyposulphite, 1300.
—— Le Blanc's process, 280–6.
—— lixiviation of black ash, 295–9.
—— picrate, 680.
—— recovery from paper liquors, 1505–8.
—— refined alkali, 302–3.
—— sources, 279–80.
—— stannate, 1303.
—— sulphate, 280–9.
—— —— Hargreave's process, 287.
—— —— Jones & Walsh's process, 286.
—— sulphopyroterebate, 1305.
—— sulphoricinoleate, 1304–5.
—— table of percentages, 302.
—— utilization of tank waste, 312.
—— water, 367.
Sodium acetate, 37.
—— —— acetic acid from, 21–2.
—— amalgam, 334.
—— arsenate, 314.
—— bicarbonate, 305.
—— carbonate, 279.
—— chloride, 1710–40.
—— hydrate, 305.
—— hyposulphite, 314.
—— iodide, 314.
—— nitrate, 315.
—— phosphates, 316,
—— silicates, 316.
—— stannate, 317.
—— stannite, 317.
—— sulphate, 317.
—— tungstates, 318.
Sod-oil, 1371.
Softening jute, 1177.
Soft soaps, 1774–7.
Sohaga (borax), 533–5.
Soie, 1741–8.
Solerie, 1748–56.
Soja hispida (oil), 1378, (spice) 1814.
Solanum spp. (starch), 1823–6.
Solar camera, 1535.
Solders, 324.
Sole-leather hides, 1218.
—— —— management in the tan-house, 1229.
—— —— treatment of, in the shed, 1231.
Solenostemma Argel (drug), 825.
Solidago odora (tea), 2010.
Solubility of salt in water, 1711.
Soluble glass, 277–8, 316.
Solvents for extracting fatty oils, 1454–5.
—— —— plant odours, 1456–7.
Sombrero hats, 920.
—— phosphate, 1264.
Somo (spice), 1802–3.
Sont (resin), 1632.
Soohgee-hoo (perfume), 1526.
Sooja (oil), 1378.
Sorbin, 1830.
Sorex indicus (perfume), 1525.
Sorghum, crushing-mills, 1911.
—— cultivation, 1909–10.
—— culture in England, 1914.
—— harvesting, 1910.
—— -juice defecators, 1912–3.
—— —— evaporators, 1911–2.
—— planting, 1909.
—— preparation of the ground, 1909.
—— qualities, 1908.
—— range, 1913–4.
—— seed, 1909.
—— soil, 1909.
—— spp. (broom-corn), 542–3, (sugar), 1908–14.
—— sugar, 1908–14.
—— —— factory, 1913.
—— —— local details, 1913–4.
—— —— manufacture, 1911–3.
—— syrup-coolers, 1913.
—— time of planting, 1909.
—— time to cut, 1910.
—— transport to mill, 1911.
—— varieties, 1908–9.
Sorting flax, 1246.
Souari-oil, 1379.
Soude, 279–318.
South American copal, 1666.
—— Sea arrowroot, 1822.
Soy, 1814.
Soymida febrifuga (resin), 1694, (timber), 2020.
Spanischer Pfeffer, 1803.
Spanish aloe, 912.
—— broom, 997.
—— flies, 796.
—— moss, 998.
—— phosphate, 1261.
—— white, 1551.
Spartina spp. (fibre), 997.
Spartium junceum (fibre), 997.
—— spp. (drug), 795.
Spathodea Rheedii (fibre), 997, (resin), 1668.
Spathsaure, 147–8.
Spearmint-oil, 1427, 1431.
Specific gravity acetic acid, 5, 26–7.
—— —— alcohols, 214–7.
—— —— ammonia, 238–9.
—— —— cane-juice, 1872.
—— —— —— sugar solutions, 1952–5.
—— —— carbonate potash, 254.
—— —— caustic potash, 251.
—— —— ferricyanide potash, 268.
—— —— ferrocyanide potash, 268.
—— —— hydrochloric acid, 3, 102–3.
—— —— lime sucrate solutions, 1930.
—— —— liquids heavier than water, 2–3.
—— —— —— lighter than water, 2.
—— —— nitrate soda solutions, 315.
—— —— nitric acid, 4, 148–50.
—— —— resins, 1622.
—— —— salt solutions, 1711.
—— —— soda, 306.
—— —— starch-sugar solutions, 1965.
—— —— sulphate potash, 278.
—— —— sulphuric acid, 3.
Specific gravity tables, 1768.
Spelter, 324.
Spence's kiln (sulphuric acid), 84.
—— processes (alum), 328, 329.
Spent tan furnace, 1228.
Spermaceti, 589, 1371–2.
Sperm-oil, 1371–2.
Sphenophorus sacchari (cane disease), 1869.
Spices and condiments, 1802–17.
—— —— aniseed, 1802–3.
—— —— bibliography, 1817.
—— —— capsicums, 1803.
—— —— caraways, 1803.
—— —— cardamoms, 1803–4.
—— —— cassia, 1804–5.
—— —— chiretta, 1805.
—— —— cinnamon, 1805–7.
—— —— cloves, 1807–8.
—— —— coriander, 1808.
—— —— galangal, 1808–9.
—— —— gentian, 1809.
—— —— ginger, 1809–10.
—— —— mustard, 1810.
—— —— nutmegs and mace, 1810–2.
—— —— pepper, 1812–4.
—— —— pimento, 1814.
—— —— soy, 1814.
—— —— vanilla, 1814–6.
Spiel-waaren, 1761–4.
Spigelia marilandica (drug), 825.
Spike, oil of, 1423.
Spikenard, 1525.
Spinacia oleracea (oxalic acid), 161.
Spinning cotton, 753.
—— jute, 1183.
—— -machines for flax, 1252.
—— rope and twine, 1697–8.
—— silk, 1751–3.
Spirit, amaranth, 1302.
—— aniline, 1302.
—— barwood, 1303.
—— bowl, 1302.
—— crimson, 1303.
—— finishing, 1302.
—— methylated, 214.
—— of Minderus, 29–30.
—— of turpentine, 1688–91.
—— orange, 1302.
—— plum, 1302.
—— proof for hats, 1111.
—— purple, 1302.
—— —— cotton, 1303.
—— red cotton, 1303.
—— scarlet, 1303.
—— —— finishing, 1302.
—— tartar, 1304.
—— varnishes, 2036–7.
—— -washing cane-sugar, 1900.
—— yellow, 1302.
Spirits, definition, 214.
—— of wine, 214.
Spiræa Ulmaria (oil), 1424.
Splints and splint-cutting (matches), 1277.
—— Beecher's filling and cutting machines (matches), 1288–92.
—— Pace's pointing machine (matches), 1282–5.
—— Young's cutting and filling machines (matches), 1286–8.
Spondia spp. (resin), 1621.
Spondias mangifera (resin), 1694.
—— sp. (oil), 1368–9.
Sponge, 1817–21.
—— bibliography, 1821.
—— process for extracting essential oils, 1457.
Spongia spp., 1817–21.
Sponia spp. (fibre), 997.
—— Wightii (coffee shade), 714.
Spreading and annealing kiln for sheet-glass, 1066.
—— frame for flax, 1247–9.
—— rubber, 1148.
Spring flowers bouquet, 1531.
Sprossenbier, 424–5.
Spruce-beer, 424.
—— fir, 2021.
—— Norway, 2014.
Spun glass, 1073.
—— silk, 1754–6.
Spurge-laurel, 818.
Spurred rye, 810.
Squalus spp. (oil), 1370–1.

Squeezers (linen bleaching), 515.
Squeezing machine (fibres), 914.
Squill, 826.
Squine, 799.
Squirrel fur, 1033.
Soant (resin), 1632.
Ssoffar (resin), 1631–2.
Stachytarpha jamaicensis (tea), 2010.
Stachytarpheta jamaicensis (tea), 2010.
Stadmannia sideroxylon (oil), 1391.
Stained glass, 1084.
Stains for glass, 1085.
—— —— hats, 1113, 1120.
Staking-knife for glove-kid (leather), 1239.
Stalagmites ovalifolius (resin), 1650.
Stamping-mill for flint, 1561.
—— soap, 1783–4.
Stannate soda, 1303.
—— sodium, 317.
Stannic chloride, 1302.
—— hydrochlorate, 1032.
—— salts, 1302.
Stannite sodium, 317.
Stannous chloride, 1301.
Staphisaigre, 826.
Staphylea primata (oil), 1379.
Star anise, 1802–3, (oil) 1417.
Starbuck Island guano, 1265.
Starch, 1821–9.
—— arrowroot, 1822–3.
—— bibliography, 1829.
—— bleaching, 1825.
—— buckwheat, 1823.
—— drying, 1825–6.
—— greenheart, 1823.
—— gum, 1645–7.
—— horse-chestnut, 1823.
—— maize, 1823.
—— paste, 623.
—— plantain, 1823.
—— potato, 1823–6.
—— rice, 1826–7.
—— sago, 1827–8.
—— sugar, 1830, 1914–21.
—— —— analysis, 1963–5.
—— —— boiling, 1915–6.
—— —— capillair-syrup and sugar, 1920.
—— —— evaporation and refining, 1917–8.
—— —— formation, 1914–5.
—— —— granulated, 1920.
—— —— manufacture, 1915–20.
—— —— neutralization and filtration, 1916–7.
—— —— other methods of manufacture, 1918–20.
—— —— packing, 1917–8.
—— —— patents, 1938–40.
—— —— principles of manufacture, 1915.
—— —— uses, 1921.
—— tapioca, 1828.
—— transformation into sugar, 1914–5.
—— washing, 1824–5, 1829.
—— wheat, 1828–9.
Starching-mangle (bleaching), 496.
Stärke, 1821–9.
Stärkegummi, 1645–7.
Stärkemehlgummi, 1645–7.
Stassfurtite, 526, 531.
Stavesacre, 826.
Steam (sulphuric acid), 64, 89.
—— boilers and pipes, lute for, 631.
—— defecators and clarifiers for cane-juice, 1885–6.
—— gauge tube (glass), 1067.
—— heated pans for cane-juice, 1891.
—— tower (sulphuric acid), 75.
—— twirl for soap-pans, 1771–3.
—— under pressure for concentrating cane-juice, 1891–2.
Steaming chest for hats, 1112.
Stearic and palmitic acids, melting and resolidifying points of mixtures of, 1464.
—— oleic, and palmitic acids, estimation of, 1463–4.
Steatornis caripensis (oil), 1376.
Stechapfel, 826.
Stecherie, 1601–20.
Steedman's process (acetic acid), 19.
Steel cylinders, engraving, 1614.
—— engraving on, 1613–4.
—— plating, 881.
Steinöl, 1433–47.
Steinsalz, 1719–24.
Stemnatopus cristata (oil), 1370.
Stenter-frames (bleaching), 504.
Stephanskörner, 826.
Steppe rue, 1324.
Sterculia acuminata (nut), 1358–9.
—— fœtida (oil), 1415.
—— spp. (fibre), 997, (resin) 1621, 1685.
—— tragacantha (resin), 1686.
Stereoscopic camera, 1535.
Stereospermum suaveolens (resin), 1694.
Stewart's defecating process (sorghum sugar), 1912–3.
Stick-all cement, 628.
Stick lac, 1668–73.
Stiefelwichse, 450–2.
Stiffening hats, 1110.
Stillingia sebifera (oil), 1412.
Stills, absinth, 218–9.
—— alcohol, 196–201, 202, 205, 206, 208–9, 212–3.
—— ammonia, 234.
—— aniline, 656.
—— bleaching powder, 457–8, 462, 466.
—— carbolic acid, 673.
—— di-ethyl aniline, 657.
—— flowers, 1457–8.
—— lime acetate, 34–6.
—— nitro-benzol, 655.
—— rosaniline, 660.
—— paraffin, 1510–2.
—— tar, 642.
—— turpentine, 1690–1.
Stinkasant, 1633–5.
Stinking nutmeg, 1812.
Stipa spp. (fibre), 997.
—— tenacissima (fibre), 979–81.
Stoat fur, 1030.
Stockholm tar, 1683.
Stockinette-machine, 1197.
Stocks, American double-shover, 1220.
—— for hides, 1220.
Stollmond for glove-kid (leather), 1239.
Stone, cement for, 626.
—— engraving on, 1614–6.
—— marten fur, 1031.
Stonemason's cement, 628.
Stoneware, 1558, 1570–3.
—— cement for, 626.
—— manufacture by expression, 1572–3.
Stones of flax, 1243.
Stoning machines (beet sugar), 1836–7.
Stoppering bottles, 1074.
Storax, 826, 1624, 1682–3.
—— liquid, 826, 1626, 1682.
Storing petroleum, 1445–6.
—— sugar-beets, 1834–5.
Stoves for salt, 1731.
Stoving hats, 1115.
Straits oil, 1368.
—— sugar-canes, 1861.
Stramoine, 826.
Stramonium, 826.
Stranding ropes, 1705.
Strands, 1696.
Strassburg turpentine, 1691.
Strauss' plan of coagulating rubber, 1664.
Straw, boiling, 1492.
—— cutting, 1492.
—— for paper, 1485.
—— treatment of, for paper-making, 1492.
Strength of terra-cotta, 1588–9.
Strengthening wine, 442.
Stricks of flax, 1243.
Striking hides, 1231.
Stringy bark, 2021.
Strombus gigas (pearl), 1517, 1520.
Strontia, 232.
—— for defecating cane-juice, 1888.
—— in sugar refining, 1928–9.
Strophanthus sp. (fibre), 998.
Struthio Camelus (feathers) 906–8, (oil) 1376.
Strychnine, 231.
Strychnos Ignatii (alkaloid), 231–2.
—— nux vomica (alkaloid), 231, 231–2, (drug) 819.
—— spp. (drug), 810, 822.
Studio, 1536.
Stuffing upper-leathers, 1234.
Sturgeon-oil, 1376.
Stormhut, 791.
Styrax spp. (resin), 1624, 1637–8, 1682–3.
Suakin gum, 1621, 1631–2.
Suave bouquet, 1531.
Substitutes for indiarubber, 1161.
Succin, 1628–30.
Succory, 631.
Sucrate of lime process (beet molasses), 1859–60.
—— — —— —— (sugar refining), 1930–3.
Sucrates of lime, 1943.
Sucre, 1830–1977.
—— de betteraves, 1831–60.
—— de la canne, 1860–1902.
—— de Saturne, 32–4.
Sucro-dextrose, 1830.
—— levulose, 1830, 1831.
Sucrose, 1830, 1942–4.
Súcuúba (resin), 1665.
Suet, 1372–3.
Sufet Bariala (fibre), 996.
Suffed-til (oil), 1388.
Suffolk coprolites, 1260.
Sugar, 1830–1977.
—— analysis, 1942–71.
—— beet-sugar, 1831–60.
—— bibliography, 1976–7.
—— cane-sugar, 1860–1902.
—— consumption, 1975.
—— maple-sugar, 1902–3.
—— melon-sugar, 1903.
—— milk-sugar, 1903–4.
—— palm-sugar, 1904–8.
—— production and commerce, 1971–5.
—— refining, 1921–35.
—— sorghum- and maize-sugar, 1908–14.
—— starch-sugar, 1914–21.
—— summary of patents, 1936–42.
—— values, 1975.
—— analysis, cane- and beet-juice, 1952–5.
—— —— characters of cane-sugar, 1942–3.
—— —— Clerget's tables, 1949–51.
—— —— determination of ash, 1946–7.
—— —— —— of crystallizable sugar, 1943–4.
—— —— —— of uncrystallizable sugar, 1944–6.
—— —— —— of water, 1946.
—— —— Fehling's method, 1948.
—— —— fermentation process, 1948.
—— —— inversion process, 1948–51.
—— —— Payen's process, 1917–8.
—— —— results, 1947.
—— —— special processes, 1947–51.
—— —— unknown organic matter, 1947.
—— beets, 1831–2.
—— —— cleansing, 1836–7.
—— —— climate for, 1832–3.
—— —— composition, 1832.
—— —— cultivation, 1831–5.
—— —— diseases, 1835.
—— —— enemies, 1835.
—— —— harvesting, 1834.
—— —— manures for, 1833.
—— —— pulp-presses, 1838–9.
—— —— purchase, 1835–6.
—— —— rasping, 1837–8.
—— —— soil for, 1833.
—— —— sowing, 1833–4.
—— —— storing, 1834–5.
—— —— transport, 1836.
—— —— washing, 1837.
—— candy, 1831.
—— cane analysis, 1955–6.
—— —— artificial manures for, 1865.
—— —— ash, analyses, 1864.
—— —— borers, 1869.
—— —— climate for, 1863.
Sugar cane composition, 1863–4.
—— —— cuttings, setting out, 1867.
—— —— defibrating, 1878.
—— —— diseases and enemies, 1868–70.
—— —— disintegrating, 1878–9.
—— —— estates, drainage, 1866.
—— —— —— irrigation of, 1866–7.
—— —— —— laying out, 1866.
—— —— —— manures produced on, 1865–6.
—— —— fallows for, 1865–6.
—— —— green-soiling for, 1865–6.
—— —— harvesting, 1868.
—— —— holing, 1867.
—— —— lining out, 1867.
—— —— manures, 1863–6.
—— —— mills, 1873–5.
—— —— —— comparison of rapid and slow, 1874–5.
—— —— —— motors for, 1875–6.
—— —— moulding and banking, 1867.
—— —— nature, 1860.
—— —— planting, 1867.
—— —— propagation, 1867.
—— —— range, 1862–3.
—— —— ratooning, 1868.
—— —— rotation, 1865–6.
—— —— sawdust methods, 1879.
—— —— soils, 1863.
—— —— —— analyses, 1864.
—— —— —— composition, 1864–5.
—— —— structure and development, 1862.
—— —— tillage for, 1865–6.
—— —— trashing, 1867–8.
—— —— varieties, 1860–2.
—— —— weeding, 1867–8.
—— —— windrowing, 1868.
—— —— yields, 1870–1.
Sugars, chemistry, 1830–1.
—— commercial, composition, 1971.
—— crystallizable and uncrystallizable in cane-juice, 1871–2.
—— —— determination, 1943–4.
—— curing, 1857.
—— definition, 1830.
—— determination, 1956–65.
—— draining, 1857, 1934–5.
—— first, second, and third, 1857.
—— formation from starch and dextrine, 1914–5.
—— in cane-juice, proportions, 1872.
—— in fruits, 1943.
—— muscovado, 1900.
—— of lead, 32–4, 1300.
—— —— for defecating cane-juice, 1888.
—— oxalic acid from, 163–4.
—— patents, brewing-sugars, starch-sugar, and invert-sugar, 1938–40.
—— —— centrifugals, 1937–8.
—— —— evaporating apparatus, 1936–7.
—— —— filtration, 1937.
—— —— sundries, 1941–2.
—— —— treatment of sugar-cane, 1936.
—— —— various chemical substances, 1940–1.
—— raw, salts in, 1927.
—— refining, 1921–35.
—— —— alcohol for, 1929–30.
—— —— alum process, 330–2, 1927–8.
—— —— bag-filters, 1922.
—— —— blow-ups, 1922.
—— —— boiling the syrup, 1926–7.
—— —— centrifugals, 1934–5.
—— —— charcoal-filters, 1922–3.
—— —— chloride of sulphur for, 1929.
—— —— composition of sugar-ashes, 1921.
—— —— dissolving the raw-sugars, 1921–2.
—— —— draining, 1934–5.
—— —— elution process, 1933–4.
—— —— lime sucrate process, 1930–3.
—— —— oxalic acid for, 1929.
—— —— preventing nuisance from char revivifying kilns, 1926.
—— —— revivifying animal charcoal, 1923–6.

Sugar refining, spent charcoal and dust for manure, 1266.
—— —— strontium for, 1928–9.
—— —— synopsis of operations, 1921–3.
—— —— tannin for, 1929.
—— scums as manure, 1266.
—— solutions, sp. gr. of, 1952–5.
—— specific rotatory power, 1962.
—— starch-sugar and other glucoses, 1914–21.
—— summary of patents, 1936–42.
—— uncrystallizable, determination, 1944–6.
Suif, 1372–3.
—— d'arbre, 1412–3.
—— de piney, 1408–9.
—— dé virola, 1377.
—— d'os, 1361.
Suint, carbonate potash from, 259–60.
Sulfure de carbon, 601–8.
Sulphate alumina, 325, 333, 1295.
—— ammonium, 246.
—— —— as manure, 1259.
—— baryta, 361.
—— copper, 1297.
—— lead, 1551.
—— potassium, 278.
—— sodium, 317.
Sulphides (sulphuric acid), 80.
—— as depilatories, 1223.
Sulphite of lime for defecating cane-juice, 1887–8.
Sulpho-acids of naphthalene, 650.
—— -carbolates, 681.
—— -carbolic acid, 681.
—— -carbonic acid, 601.
—— -compounds of anthraquinone, 654.
—— -pyroterebate of soda, 1305.
—— -ricinoleate ammonia, 1304–5.
—— —— soda, 1304–5.
Sulphur and chlorine compounds for defecating cane-juice, 1888.
—— as a mordant, 1300.
—— chloride for sugar-refining, 1929.
—— from coal-gas, 241.
—— —— soda waste, 313.
—— in pyrites, estimating, 87.
—— refining (gunpowder), 885.
Sulphuric acid, 51–101.
—— —— air in chambers, 61–4, 88–9.
—— —— anhydrous, 96–9.
—— —— brimstone kilns, 52–3, 56–7.
—— —— chambers, 52–4.
—— —— —— construction, 54–6.
—— —— commerce, 100–1.
—— —— commercial sources, 52.
—— —— concentration, 92–6.
—— —— consumption of nitre or nitric acid, 79.
—— —— direction of gases through the chamber, 65–7, 90.
—— —— division of labour, 67–9, 90.
—— —— draught in chambers, 61–4, 88–9.
—— —— estimating nitric acid in, 70.
—— —— —— oxygen in escaping gases, 71–2.
—— —— —— sulphur in pyrites, 87.
—— —— —— sulphurous acid in the gases, 70–1.
—— —— from sulphides, 80–92.
—— —— ice-machines, 1140.
—— —— nitric acid supply, 58–60.
—— —— other proposed methods of producing, 100.
—— —— properties, 51–2.
—— —— proportion of sulphur to chamber space, 78.
—— —— pyrites combustion, regulating, 87–8.
—— —— —— for, 80.
—— —— —— kilns, 80–7.
—— —— rationale of manufacture, 52–4.
—— —— recovery of nitrogen compounds, 72–8.
Sulphuric acid, removal of arsenic from, 90–2.
—— —— sources, 52.
—— —— specific gravity, 3.
—— —— steam for, 56, 89–90.
—— —— —— in chambers, 64–5, 89–90.
—— —— strength of chamber acid, 69–70.
—— —— temperature for kilns and chambers, 60–1, 88.
—— —— testing chamber drips, 69–70.
—— —— —— —— gases, 70–2.
—— —— the make of acid, 79–80.
—— —— uses, 100.
—— —— working results, 78–80, 90.
—— —— works, 52–4.
—— anhydride, 51, 96–9.
Sulphurous acid for defecating cane-juice, 1888.
—— —— gas (sulphuric acid), 70.
Sumach, 1988–92.
Sumatra benzoin, 1637.
—— rubber, 1664.
Sumbul, 826, 1525.
Sunflower (fibre), 961, (oil), 1411.
Sunn hemp, 946.
Superphosphates, 1259.
Supports for firing ware, 1581–2.
Surgiha (perfume), 1526.
Suriga (perfume), 1526.
Suspender liquors, 1229–30.
Süssholz, 816–7.
Sweating hides, 1222.
Sweet-briar extract, 1528.
—— flag-oil, 1431.
—— gum, 1682–3.
—— pea extract, 1529.
—— wood, 797.
Swietenia Chloroxylon (resin), 1682.
—— Mahogani (gunpowder), 884, (resin) 1673.
—— spp. (timber), 2017.
Sword-sedge, 963.
Sycamore, 2021.
Sykes' hydrometer, 215.
Sympathetic inks, 1168.
Symplocos cratægioides (oil), 1415.
Synanthron, 1830.
Syrian rue, 1324.
—— swallow-wort, 920.
Syringa vulgaris (oil), 1424.
Syrup, definition, 1831.

TABERNÆMONTANA crassa (resin), 1656.
—— spp. (resin), 1627, 1665.
—— utilis (resin), 1624.
Tables of actual densities of oils and fats, 1469–70.
—— analyses of clays, 1559.
—— —— —— pottery ware, 1558.
—— —— —— terra-cotta and tile clays, 1583.
—— cost of illumination, 1547.
—— fatty acids, 1765.
—— full reactions of all the usual oils, 1472–5.
—— ingredients of earthenware, 1575.
—— linen yarn, 1254.
—— phosphoric acid in phosphates and superphosphates, 1265.
—— strengths of terra-cotta, 1588–9.
—— sugar in cane-juice, 1872.
—— water and glycerine in mixtures, 1801.
Tacamahaca resin, 1624, 1683.
Tacca spp. (starch), 1822.
Taches for cane-juice, 1890–1.
Tachypetis aquila (oil), 1375.
Tacuma (cane disease), 1869.
Ta-fung-tsze (oil), 1382.
Tahiti arrowroot, 1822.
—— chestnut, 1353.
Talca gum, 1621, 1631–2.
Talch, 1631–2.
Talg, 1372–3.
Talha gum, 1631–2.
Talipot palm, 946.
Tallicoona-oil, 1395–6.
Tallow, 579, 1372–3.
—— oil in an ordinary oil, estimation of, 1469.
Tallow rendering, 1447–8.
—— [vegetable], 1412–3.
Tamanu (oil), 1387–8, (resin) 1624, 1683, (timber) 2021.
Tamarak wood, 2016.
Tamarinds, 826, 1028.
Tamarind [Manilla] oil, 1415.
Tamarindus indica (drug), 826, (fruit) 1028, (oil) 1415, (resin) 1694.
Tamarinha plant as a source of citric acid, 50.
Tamarix dioica (resin), 1694.
—— spp. (drug), 818.
Tambooti (timber), 2016.
Tan, furnace for spent, 1228.
Tanacetum vulgare, 1431.
Tanakaha wood, 2021.
Tan-house, management of sole-leather in, 1229.
Tank salt-pans, 1736–7.
Tannage of common and shaved hides, 1232.
—— for shaved hides, 1233.
Tannenharz, 1679–80.
Tanneries, construction, 1228.
Tannin, 50, 1977–94.
—— algarobilla, 1982.
—— bibliography, 1994.
—— chestnut-extract, 1982.
—— cutch, 1982–3.
—— definition, 1977.
—— divi-divi, 1983.
—— for sugar-refining, 1929.
—— galls, 1983–4.
—— gambier, 1984–5.
—— general chemistry, 1977–80.
—— hemlock, 1985.
—— mimosa or wattle, 1986–7.
—— miscellaneous, 1993–4.
—— myrobalans, 1987.
—— oak barks, 1987–8.
—— quantitative determination, 1980–2.
—— quebracho, 1988.
—— sumach, 1988–92.
—— valonia, 1992–3.
Tanning materials, 1226.
—— —— exhausting, 1226.
—— —— grinding, 1226.
—— preparation of hides for, 1219.
—— woods refuse for acetic acid, 15–19.
Tansy-oil, 1431.
Tape rubber, 1146.
Tapioca, 1828.
Tapir-grease, 1376.
Tapirus suillus (oil), 1376.
Tapis, 2095–2106.
Tapping trees, methods of, 803, 817, 1639, 1651, 1653, 1655, 1656, 1658, 1659, 1661, 1662, 1664, 1677, 1684, 1686, 1687–9, 1691, 1692, 1902–3, 1905–6.
Taps (tanning), 1228.
Tar, coal, ammonia from, 235.
—— —— distillation, 42–3.
—— [mineral], 1433–47.
—— oven, 1683.
Tars, 1683–4.
Taraxacum, 826.
—— spp. (drug), 826.
Tarragon-oil, 1431.
Tarring rope, 1709–10.
Tartar, 1303.
—— emetic, 190.
—— refining, 184.
—— sable fur, 1031.
—— spirits, 1304.
Tartaric acid, 174.
—— —— adulteration, 184–9.
—— —— German method of manufacturing, 182–4.
—— —— manufacture, 174–84.
—— —— occurrence, 174.
—— —— properties, 189.
Tartrate lime, from crude tartar, 182.
—— —— tartaric acid from, 184.
—— potassium, 279.
Tartrates, 189–90.
Tartre brut, 335.
Tassoc-oil, 1376.
Tauwerk, 1695–1710.
Tawhero towai (tannin), 1994.
Tawing leather, 1237.
Taxus spp. (timber), 2022.
Tayches for cane-juice, 1890–1.
Taylor and Ramsden's spindle (cotton manufacture), 765.
Taylor's bag filters, 1889, 1922.
Tchalleh (borax), 533–5.
Tea, 425, 1994–2011.
—— adulterants and substitutes, 2010–1.
—— bibliography, 2011.
—— brick, 2006–7.
—— commerce and values, 2011.
—— cost of a garden, 2004–5.
—— cost of manufacture, 2006.
—— cultivating and pruning, 1996.
—— cultivation, 1994–8.
—— diseases and enemies, 1997.
—— Faham, 1528.
—— fermenting, 2001.
—— filling up vacancies, 1996–7.
—— firing and dholing, 2001.
—— flushes and picking, 1997–8.
—— forming a garden, 1995.
—— green, 2001–2.
—— Labrador, 1308.
—— manufacture, 1998–2007.
—— manures, 1997.
—— oil, 1411, 1431.
—— (Labrador) oil, 1430.
—— packing, 2004.
—— planting, 1996.
—— production and commerce, 2007–10.
—— qualities, 1998–9.
—— rolling, 1999.
—— sifting and sorting, 2002–4.
—— soil and situation, 1995.
—— sowing, 1994–5.
—— sunning, 2001.
—— tools, 1996.
—— withering, 1999.
Tea-rose extract, 1529.
Teaches for cane-juice, 1890–1.
Teak, 2021.
—— African, 2018.
—— tar, 1684.
Teazle, 2084.
Tecoma pentaphylla (tannin), 1994.
Tectona grandis (resin), 1668, 1684, (timber) 2021.
Teesoo (dye), 867.
Tegrodera erosa (drug), 797.
Teinture, 827–54.
Telegraph cores, 1152, 1162–3.
—— wires, insulating, 1151.
Telfairia pedata, 1415.
Teliya (borax), 534.
Tempering cane-juice, 1886–7.
Tendoo (resin), 1684.
Tension of carbonic anhydride, 46.
Tephrosia spp. (dye), 858.
Teppich, 2095–2106.
Térébinthine d'Alsace, 1691.
—— de Briançon, 1691–2.
—— du Canada, 1686–7.
—— des Carpathes, 1687.
—— de Chio, 1687.
—— de Chypres, 1687.
—— au citron, 1691.
—— commune, 1687–91.
—— d'Hongrie, 1691.
—— du mélèze, 1691–2.
—— du sapin, 1691.
—— —— —— baumier, 1686–7.
—— de Strasbourg, 1691.
—— Suisse, 1691–2.
—— de Venise, 1691–2.
Teriak-e-arabistani (narcotic), 1312.
Terminalia Arjuna (wax), 2045.
—— Benzoin (resin), 1638.
—— coriacea (timber), 2018.
—— latifolia (timber), 2013.
—— spp. (oil), 1396, (resin) 1624, 1638, 1694, (tannin) 1987.
—— tomentosa (resin), 1668.
Terracotta, 1558, 1582–7.
—— clays, table of analyses, 1583.
—— fire-proof, 1586–7.
—— kilns, 1584–5.
—— materials, 1583.
—— modelling, 1585–6.
—— moulding by machinery, 1586.
—— strength, 1587–9.
Terra japonica, 1982–3, 1984–5.
Terre foliée minérale, 37–8.

Tesselated and tile pavements, 1587-94.
Testing cured indiarubber goods, 1158.
—— indiarubber sheet, 1153.
—— —— thread and tape, 1157.
—— petroleum, 1179–81.
—— —— waterproof fabrics, 1153–4.
—— wine, 441.
Tests for oils, miscellaneous special, 1476–7.
Tetranthera laurifolia (oil), 1413.
Tetraonyx spp. (drug), 797.
Teutelsdreck, 1633–5.
Texan snake-root, 825.
Thaleichthys pacificus (oil), 1366.
Thalictrum foliolosum (drug), 809.
Thallium glass, 1082.
Thapsia garganica (resin), 1624.
Thea chinensis (oil), 1411.
—— spp. (beverage), 425, (tea) 1994–2011.
Thénard's process for purifying oils and fats, 1459–60.
Theobroma Cacao (beverage), 421–2, (oil) 1379.
—— oil, 1379.
—— spp. (cocoa), 684–91.
Thermometer-tube, 1073.
Thespesia populnea (oil), 1415.
—— spp. (fibre), 998, (resin) 1694.
Thibet goat-hair, 1097.
Thilorier's apparatus (carbonic acid), 46.
Thiocarbonic anhydride, 601.
Thior (resin), 1652.
Thit-tsi (resin), 1692.
Thlaspi spp. (oil), 1415.
Thom's sulphuring stove (bleaching), 513.
Thon, 635–40.
Thorn-apple, 826, 1325.
Thorn's experiments (oxalic acid), 170.
Thoura gum, 1647–8.
Thran, 1374–5.
Thread bleaching (cotton), 506–8.
—— rubber, 1146.
Threads, 1696.
Thridace, 815.
Throstle frame (cotton manuf.), 760.
Throwing pottery, 1576.
—— wheels, 1561–3.
Thrown silk, 1754.
Thus, 1684, 1688.
Thuja articulata (resin), 1681.
—— occidentalis (oil), 1433.
Thyme-oils, 1431.
Thymus spp. (oil), 1431.
—— vulgaris (oil), 1373–4.
Thymol, 578.
—— soap, 1789.
Ti fibre, 919.
Tia (tea), 2011.
Tibisiri fibre, 982.
Tiftik, 1096.
Tiger fur, 1033.
Tiglium officinale (drug), 809, (oil) 1386–7.
Tikhar (starch), 1882.
Tikor (starch), 1822.
Tilâm-outan (oil), 1425.
—— wangi (oil), 1425.
Tile clays, table of analyses, 1583.
—— encaustic, 1587–94.
—— from waste glass, 1087.
—— pavements, 1587–94.
—— roofing, 1572–3.
Tilia europæa (oil), 1424.
—— parviflora (oil), 1415.
—— spp. (fibre), 998.
Tillandsia usneoides (fibre), 998.
Til-oil, 1388–90.
Timber, 2012–23.
—— acacia, 2012.
—— alder, 2012.
—— alerce, 2012.
—— alerse, 2012.
—— asb, 2012.
—— assegai, 2012.
—— beech, 2012–3.
—— bibliography, 2023.
—— birch, 2013.
—— box, 2013.
—— broadleaf, 2013.
—— bullet tree, 2013.
Timber, cedar, 2013–4.
—— chestnut, 2014.
—— commerce, 2022–3.
—— cypress, 2014.
—— deal, 2014.
—— deodar, 2014.
—— dogwood, 2015.
—— doornboom, 2015.
—— ebony, 2015.
—— elm, 2015.
—— for match-splints, 1277, 1279.
—— fir, 2015.
—— greenheart, 2015.
—— gum, 2015.
—— hickory, 2015–6.
—— ironbark, 2016.
—— ironwood, 2016.
—— jack, 2016.
—— jarrah, 2016.
—— kanyin, 2016.
—— kauri, 2016.
—— larch, 2016.
—— lignum-vitæ, 2016–7.
—— locust-tree, 2017.
—— mahogany, 2017.
—— mango, 2017.
—— maple, 2017.
—— miro, 2017.
—— mora, 2017–8.
—— mutti, 2018.
—— nan-mu, 2018.
—— naugiia, 2018.
—— neem, 2018.
—— oak, 2018.
—— pai-ch'ha, 2018.
—— pear, 2018–9.
—— persimmon, 2019.
—— pine, 2019–20.
—— plane, 2020.
—— poon, 2020.
—— poplar, 2020.
—— pymma, 2020.
—— pynkado, 2020.
—— rata, 2020.
—— rohun, 2020.
—— rosewood, 2020.
—— sabicu, 2020.
—— sal, 2020–1.
—— satin-wood, 2021.
—— sissu, 2021.
—— sneezewood, 2021.
—— spruce, 2021.
—— stringy bark, 2021.
—— sycamore, 2021.
—— tamanu, 2021.
—— tanakaba, 2021.
—— teak, 2021.
—— toon, 2021.
—— totara, 2022.
—— walnut, 2022.
—— willow, 2022.
—— yellow-wood, 2022.
—— yew, 2022.
Timiti (nut), 1357.
Tin acetate, 39.
—— amalgam, 334.
—— and ammonium chloride, 1303.
—— assay of, 357.
—— bichloride, 1302.
—— crystals, 1301.
—— detection, 349.
—— in muriates, estimation, 1301.
—— in soda stannate, estimation, 1303.
—— mordants, 1301.
—— nitrate, 1302.
—— oxalate, 1302.
—— oxymuriates, 1303.
—— per-salts, 1302.
—— protochloride, 1301, 1302.
—— pulp, 272–3.
—— solution, 1303.
Tincal, 533–5.
Tinea oleella, 1400.
—— sp. (resin), 1671.
Tinospora spp. (drug), 811.
Tipples of flax, 1244.
Tipuana speciosa (tannin), 1988.
Tisso (dye), 867.
Tissures, 1761–4.
Tiza (borax), 538.
Tobacco, 1325–50.
—— adulteration and substitutes, 1349–50.
—— after-cultivation, 1330.
—— bulking, 1332.
Tobacco, cake or plug, 1342.
—— camphor, 578.
—— cigarettes, 1345–6.
—— cigars, 1344–5.
—— climate, 1325–6.
—— cutting, 1341–2.
—— damping, 1340.
—— drying, 1331–2, 1342.
—— harvesting, 1330–1.
—— imports, duties, and values, 1350.
—— improving, 1333.
—— in various countries, 1333–40.
—— manures, 1326–7.
—— miscellaneous appliances, 1346–7.
—— nature and properties, 1348–9.
—— packing, 1332–3.
—— planting, 1329–30.
—— preparation and use, 1340–8.
—— —— of the field, 1329.
—— production and commerce, 1333–40.
—— roll or twist, 1342–4.
—— rotation, 1327.
—— seed, 1328.
—— —— -beds, 1328–9.
—— —— -oil, 1411.
—— selection of sort, 1327–8.
—— situation, 1326.
—— snuff, 1346.
—— soil, 1326.
—— sorting, 1332.
—— stripping, 1332.
—— —— and sorting, 1340–1.
—— topping and suckering, 1330.
Toddalia aculeata (drug), 817.
Toddy, 425.
Tœnia Solium, 815.
Toi (fibre), 945.
Toi oil, 1415.
Toilet soaps, 1789–92.
Tokio-purple, 867.
Tollkraut, 794.
Tolomane (starch), 1822.
Tolu balsam, 1623, 1625, 1684–5.
—— —— extract, 1529.
Toluidine, 659, 663.
—— blue, 666.
—— green, 669.
Toluifera Balsamum (resin), 1684–5.
Toluol, 648, 2026.
Toluylamine, 669.
Tomarus bituberculatus (cane disease), 1869.
Tonga-beans, 1528.
Toning photographic prints, 1540.
Tonite, 897.
Tonka-beans, 1528.
Tonquin-beans, 1528.
—— —— extract, 1529.
Tools for boxing pines, 1689.
—— —— hatters, 1121–5.
—— used in salt-making, 1717.
Toon wood, 2021.
Topaz, 1043.
Töpferwaare, 1556–1601.
Torreya Myristica, 1812.
Torula cerevisiæ (ferment), 1830.
Totara wood, 2022.
Touchardia latifolia (fibre), 998.
Toughened glass, 1079.
Tougheners (varnish), 2027.
Toulema (starch), 1822.
Touloula (starch), 1822.
Touloumaca (oil), 1386.
Toun-tilâm (oil), 1425.
Tous-les-mois (starch), 1822.
Toute-épice, 1814.
Tow, carding-engines for, 1251–2.
—— preparation of, 1251.
Towers, hydrochloric acid, 110–6.
Town tallow, 1372.
Trachylobium mossambicense [Hornemannianum] (resin), 1641.
—— spp. (resin), 1623, 1666.
—— verrucosum (resin), 1642.
Tradescantia discolor (oxalic acid), 161.
Tragacanth, 1621, 1685–6.
Traganth, 1685–6.
Train-oil, 1374–5.
Translucent pottery, 1594–7.
Transparent soaps, 1792.
Transportation of petroleum, 1443–5.
Trapa spp. (nut), 1359.
Trashing sugar-canes, 1867–8.
Treacle. See also Molasses.
—— oxalic acid from, 163–4.
Tree copal, 1641.
—— mallow (fibre), 963.
—— oil, 1411–2.
Trees for shade and shelter (coffee), 710–1, 714, 716, 719, 720.
Trehalose, 1830.
Tri-amido-azo-benzol, 658.
Trichecus Rosmarus (ivory), 1175, (oil), 1374.
Trichilia spp. (oil), 1415.
Tridacna gigas (pearl), 1517, 1520.
Trigonella fœnum-græcum (oil), 1415.
Trimming hats, 1117.
—— silk hats, 1127.
Trimmings, 1762.
Trinidad goat-sucker (oil), 1376.
Trink's filter press (beet-sugar),1848.
Triodia irritans (fibre), 998.
Triphenyl-mauvaniline, 666, 668.
—— -roso-toluidine, 666.
Triple-effect vacuum-pans, 1895–8.
—— rose extract, 1529.
Triptolemæa spp. (timber), 2020.
Triticum vulgare (starch), 1828–9.
Tri-toluyl-rosaniline, 666.
Tritoma spp. (fibre), 998.
Tropæolum majus (oil), 1433.
Tropical African rubbers, 1655.
True Bishop's weed, 791.
—— storax, 1682.
Trypograph, 1609.
Tshoochal (borax), 534.
Tuberose extract, 1529.
Tubes, glass, 1072.
Tubipora musica (coral), 1521.
Tub-sizing paper, 1500–1.
Tucum-oil, 1411.
—— thread, 920.
Tulip bouquet, 1531.
Tulpin's singeing-machine (bleaching), 474.
Tumbeki (narcotic), 1350.
Tumbler for washing hides, 1232.
Tunfischöl, 1373–4.
Tung-oil, 1411–2.
Tungstates sodium, 318.
Tungsten, detection of, 349.
Tunny-oil, 1373–4.
Turbinella Scolymus (pearl), 1517.
Turbo spp. (pearl), 1517.
Turkey galls, 1983–4.
—— gum, 1631.
—— opium, 1309–11.
—— tobacco, 1338–9.
Turkeys for destroying insects (tobacco), 1330, (sugar-cane), 1869.
—— grease, 1376.
Turkey-red bleach, 494.
Turkish silk, 1744.
Turk's cap (pearl), 1517.
Turmeric, 868.
Turned buttons, 559.
Turners' cement, 626.
Turning pottery, 1576.
Turpentine, 1624, 1686–92, 2025–6.
—— oils, 1431, 1688–91.
—— stills, 1690–1.
Turps, 2025–6.
Turquois, 1043.
Turtle-butter, 1376–7.
Turtosa wood, 2018.
Tusser silkworms, 1745–6.
Tussock-grass, 999.
Tutu (tannin), 1993.
Twin rose extract, 1529.
Twines, 1696.
—— factories, 1697.
Twist tobacco, 1342–4.
Twisting hats, 1109.
—— -in cotton, 779.
—— rope and twine, 1699–1701.
Tylophora asthmatica (drug), 814.
Type metal, 324.
—— writing machines, 1606–8.
Typha elephantina (fibre), 999.

UCUHUBA (oil), 1379.
Ulé (resin), 1659–61.
Ulmus spp. (gunpowder), 884, (timber), 2015.

Ulrich's scarlet, 662.
Ultramarine, 1548.
Unboiled salts, 1732–3.
Unbreakable glass, 1079.
Uncaria spp. (tannin), 1984–5.
Uncrystallizable sugar, determination, 1944–6.
—— —— in cane-juice, 1871–2.
Unhairing hides, 1220.
Unio spp. (pearl), 1517.
Union hide-splitter, 1233.
Universal cement, 628.
Unsworth's doubling-winding frame, 1698–9.
Upholstery hair, 1100.
Upper-leathers, drying, 1234.
—— —— measuring, 1235–6.
—— —— oiling, 1234–5.
—— —— stuffing, 1234.
Urceola elastica (rubber), 1657–8, 1664.
—— esculenta (rubber), 1657.
Urena spp. (fibre), 999.
Urginea spp. (drug), 825–6.
Urostigma spp. (rubber), 1628, 1655, 1656.
—— vogelii (rubber), 1655–6.
Ursus spp. (fur), 1030.
Urtica spp. (fibre), 921–32, 999.
Usebe's green, 668.
Ushak (resin), 1630.
Usquebaugh, 227.
Ustilago sacchari on sugar-cane, 1870.
Utilization of tank waste (soda), 312–3.

VACCINIUM vitis-idæa (drug), 794.
Vachellia Farnesiana (resin), 1694.
Vacoua for shade, 1815.
Vacuum-chest for curing cane-sugar, 1901.
—— pan (tartaric acid), 176–7.
—— pans for sugar-solutions, 1856–7, 1893–8.
—— —— multiple effects, 1895–8.
—— —— patents, 1936–7.
—— —— working, 1893–5.
—— —— —— (sugar-refining), 1926–7.
Vahea spp. (rubber), 1627, 1654, 1656.
Valerian, 826.
—— oil, 1431.
Valeriana officinalis (drug), 826.
Valonia, 1226, 1992–3.
Valuation of soap, 1792–6.
Valve-cutting (indiarubber), 1150.
Vanilla, 227, 1528, 1814–6.
—— extract, 1529.
—— spp. (spice), 1814–6.
Varec, potash from, 263–5.
Variolaria spp. (oxalic acid), 161.
Varnish, 2023–38.
—— black oil-, and japans, 2035.
—— boiled oils, 2029–31.
—— clarifying oil, 2024.
—— classification, 2023, 2028.
—— definition, 2023.
—— driers, 2027–8.
—— drying oils, 2023–4.
—— essence-, 2035–6.
—— essence-varnish resins, 2024.
—— essential-oil, 2035–6.
—— ether, 2037.
—— French polish, 2037.
—— gums, &c., used in water-varnishes and glazes, 2025.
—— lead oils, 2030.
—— manganese and lead oils, 2030–1.
—— —— oils, 2030.
—— manufacture, 2028–38.
—— materials, 2023–8.
—— mixed-solvent, 2038.
—— oiled silk, 2032.
—— oil-varnishes, 2032–5.
—— oil-varnish resins, 2024.
—— oleo-resinous, 2035–6.
—— resins, 2024–5.
—— spirit, 2036–7.
—— spirit lacquers, 2037.
—— spirit-varnish resins, 2024.
—— stoved japans and enamels, 2031–2.
Varnish, tougheners, 2027.
—— volatile solvents, 2025–7.
—— water-, 2038.
Varnishes (indiarubber), 1158.
—— (natural), 1692.
Varnishing indiarubber textures, 1158.
Varnish tree, 2044.
Vaseline, 1447.
Vastris gigas (oil), 1376.
Vateria indica (oil), 1408–9, (resin) 1624.
Vatica laccifera (resin), 1668, 1671.
—— spp. (resin), 1624, 1644, 1678.
Vatting and fining (beer), 411.
Vegetable albumen, 192.
—— bristles, 919.
—— fibres, 909–1000.
—— fixed oils and fats, extraction of, 1451–5.
—— oils and fats [fixed], 1377–1415.
—— —— —— almond, 1377.
—— —— —— American nutmeg, 1377.
—— —— —— argan, 1377–8.
—— —— —— assai, 1378.
—— —— —— bean, 1378.
—— —— —— beech, 1378.
—— —— —— ben, 1378–9.
—— —— —— bicuhiba, 1379.
—— —— —— bladder-nut, 1379.
—— —— —— boma, 1379.
—— —— —— butter-nut, 1379.
—— —— —— cacao, 1379.
—— —— —— calaba, 1379.
—— —— —— carmaru, 1379.
—— —— —— cashew, 1379.
—— —— —— castanha, 1379–80.
—— —— —— castor, 1380–2.
—— —— —— chaulmugra, 1382.
—— —— —— chequito, 1382.
—— —— —— cherry, 1382–3.
—— —— —— chironji, 1383.
—— —— —— cocculus indicus, 1383.
—— —— —— coconut, 1383–4.
—— —— —— colza, 1384–5.
—— —— —— coquito, 1385.
—— —— —— cotton-seed, 1385–6.
—— —— —— coumu, 1386.
—— —— —— crab, 1386.
—— —— —— croton, 1386–7.
—— —— —— dika, 1387.
—— —— —— dilo, 1387–8.
—— —— —— dogwood, 1388.
—— —— —— gamboge, 1388.
—— —— —— gingelly, 1388–90.
—— —— —— gold - of - pleasure, 1390.
—— —— —— grape-stone, 1390–1.
—— —— —— ground-nut, 1391.
—— —— —— hazel-nut, 1391.
—— —— —— hempseed, 1391.
—— —— —— hickory-nut, 1391–2.
—— —— —— horse-chestnut, 1392.
—— —— —— illipi, 1392.
—— —— —— jupati, 1392.
—— —— —— kanari, 1392.
—— —— —— katiow, 1392.
—— —— —— keenatel, 1392.
—— —— —— kikuel, 1392.
—— —— —— kukui, 1392–3.
—— —— —— kurung, 1393.
—— —— —— lallemantia, 1393.
—— —— —— laurel, 1393.
—— —— —— linseed, 1393–4.
—— —— —— mabo, 1394.
—— —— —— macassar, 1394.
—— —— —— madia, 1394.
—— —— —— mahwa, 1394.
—— —— —— mamey, 1394–5.
—— —— —— mangosteen, 1395.
—— —— —— margosa, 1395.
—— —— —— melon, 1395.
—— —— —— miscellaneous, 1413–5.
—— —— —— moodooga, 1395.
—— —— —— mote-grease, 1395–6.
—— —— —— m'poga, 1396.
—— —— —— mustard, 1396.
—— —— —— myrobalan, 1396.
—— —— —— niger, 1396.
—— —— —— nounga, 1396.
—— —— —— nutmeg, 1396–7.
—— —— —— ochoco, 1397.
—— —— —— odal, 1397.
Vegetable oils and fats [fixed], okro, 1397.
—— —— —— olive, 1397–1406.
—— —— —— ouabe, 1406.
—— —— —— owala, 1406.
—— —— —— palm, 1406–8.
—— —— —— palm-nut, 1408.
—— —— —— phulwara, 1408.
—— —— —— pine, 1408.
—— —— —— piney, 1408–9.
—— —— —— piquia, 1409.
—— —— —— pistachio, 1409.
—— —— —— plum, 1409.
—— —— —— poondy, 1409.
—— —— —— poppy, 1409–10.
—— —— —— pulza, 1410.
—— —— —— safflower, 1410.
—— —— —— shea, 1410.
—— —— —— simbolee, 1410.
—— —— —— siringa, 1411.
—— —— —— soap-nut, 1411.
—— —— —— sunflower, 1411.
—— —— —— tea, 1411.
—— —— —— tobacco, 1411.
—— —— —— tucum, 1411.
—— —— —— tung, 1411–2.
—— —— —— vegetable tallow, 1412–3.
—— —— —— walnut, 1413.
—— —— —— zachun, 1413.
—— hair, 998.
—— horsehair, 938, 1101.
—— ivory, 1357.
—— oils [volatile and essential], 1415–33.
—— —— acorn, 1415.
—— —— albahaca, 1416.
—— —— allspice, 1416.
—— —— almond, 1416.
—— —— aloes, 1416.
—— —— amber, 1416.
—— —— angelica, 1416.
—— —— angostura, 1416.
—— —— aniseed, 1416–7.
—— —— anise (star), 1417.
—— —— asafœtida, 1417.
—— —— avens, 1417.
—— —— balm, 1417.
—— —— bayberry, 1417.
—— —— benzoin, 1417.
—— —— bergamot, 1417.
—— —— birch, 1417–8.
—— —— cajuput, 1418.
—— —— caraway, 1418–9.
—— —— cardamom, 1419.
—— —— cascarilla, 1419.
—— —— cedar, 1419.
—— —— cedrat, 1419.
—— —— celery, 1419.
—— —— chamomile, 1419.
—— —— cinnamon and cassia, 1419.
—— —— citronella, 1419–20.
—— —— clove, 1420.
—— —— clove-bark, 1420.
—— —— coffee, 1420.
—— —— copaiba, 1420.
—— —— coriander, 1420.
—— —— cubebs, 1420.
—— —— dill, 1420.
—— —— elder, 1420.
—— —— elemi, 1420.
—— —— eucalyptus, 1420–1.
—— —— fennel, 1421.
—— —— fusel, 1421.
—— —— galangal, 1421.
—— —— galbanum, 1421.
—— —— gale, 1421.
—— —— garlic, 1421.
—— —— geranium, 1421.
—— —— ginger, 1421.
—— —— ginger-grass, 1422.
—— —— hop, 1422.
—— —— hyssop, 1422.
—— —— ilang-ilang, 1422.
—— —— iva, 1422.
—— —— jasmine, 1422.
—— —— jonquil, 1422.
—— —— juniper, 1422.
—— —— laurel, 1422–3.
—— —— lavender, 1423.
—— —— lemon, 1423.
—— —— lemon-grass, 1423–4.
—— —— lilac, 1424.
—— —— linden, 1424.
—— —— mace, 1424.
—— —— marjoram, 1424.
Vegetable oils [volatile and essential], matico, 1424.
—— —— meadow-sweet, 1424.
—— —— mehudi, 1424.
—— —— mignonette, 1424.
—— —— milfoil, 1424.
—— —— miscellaneous, 1432–3.
—— —— mugwort, 1424.
—— —— mustard, 1424.
—— —— myrrh, 1424.
—— —— myrtle, 1424.
—— —— nasturtium, 1425.
—— —— neroli, 1425.
—— —— olibanum, 1425.
—— —— orange, 1425.
—— —— orris, 1425.
—— —— parsley, 1425.
—— —— patchouly, 1425.
—— —— pepper, 1425.
—— —— peppermint, 1425–7.
—— —— petit-grain, 1427.
—— —— pine, 1427.
—— —— poplar, 1427.
—— —— pyrethrum, 1427.
—— —— rose, 1427–30.
—— —— rosemary, 1430.
—— —— rosewood, 1430.
—— —— rue, 1430.
—— —— saffron, 1430.
—— —— sagapenum, 1430.
—— —— sage, 1430.
—— —— sandal-wood, 1430.
—— —— sassafras, 1430–1.
—— —— savin, 1431.
—— —— spearmint, 1431.
—— —— sweet-flag, 1431.
—— —— tansy, 1431.
—— —— tarragon, 1431.
—— —— tea, 1431.
—— —— thyme, 1431.
—— —— turpentine, 1431.
—— —— valerian, 1431.
—— —— winter-green, 1431–2.
—— —— wormseed and wormwood, 1432.
—— silk, 921, 939, 998.
—— substances, oxalic acid from, 163.
—— tallow, 1412–3.
Vegetables, preserving, 1017–8.
Veilchenwurzel, 1526–7.
Vélanèdes, 1992–3.
Veluring hats, 1119.
Venetianischer terpentin, 1691–2.
Venice turpentine, 1691–2.
Ventilago maderaspatana (dye), 864.
Venuleth's potato-washer, 1823–4.
Vepris lanceolata (timber), 2016.
Vera Cruz elemi, 1649.
Veratrum officinale (drug), 798.
—— spp. (drug), 812.
Verbena extract, 1529.
—— oil, 1423.
—— satchet, 1532.
Verdigris, 30, 1297.
Verek (resin), 1631.
Veridine, 681.
Vermilion, 1550.
Vernis, 2023–38.
Vernonia anthelmintica (oil), 1415.
Vert-de-gris, 30–1.
Vestas, 1277, 1292.
Vesuvians, 1277, 1292.
Viburnum cassinoides (tea), 2010.
Vicia spp. (oil), 1416.
Vichy water, 365.
Vicuna, 1093.
Vienna green, 1549.
—— multicopyist, 1610.
Vikunia (spice), 1808.
Vinaigre, 2038–42.
Vinasses, potash from, 257–9.
Vinegar, 6, 2038–42.
—— acetic acid from, 25–6.
—— [brandy], acetic acid from, 23.
—— acetification, 2040.
—— aromatic, 335.
—— bibliography, 2042.
—— commerce, 2042.
—— fermentation, 2039.
—— fining, 2039–40.
—— generator, 7.
—— grain or malt, 2038–41.
—— other vinegars, 2042.
—— quick German process, 2041–2.
Vines, potash from, 255.

Vintage, 435.
Violacine, 681.
Violaniline, 668.
Violet de Paris, 668.
—— extract, 1529.
—— satchet, 1532.
—— soap, 1792.
Virola sebifera (oil), 1377.
Viscous fermentation (alcohol), 196.
Vismia spp. (resin), 1624, 1650, 1668.
Vison lutreola (fur), 1031–2.
Vitex sp. (nut), 1351, (oil), 1379.
Vitis vinifera (fruit), 1023–4, 1027–8, (oil), 1390–1.
Vitivert extract, 1529.
Viverra spp. (fur), 1030, (perfume) 1524.
Voà-canja, &c. (rubber), &c., 1654.
Volandero (fibre), 938.
Volatile oils, extraction of, 1456–9.
—— vegetable oils, 1415–33.
Volcanic ammonia, 243.
Volkameria extract, 1529.
Volunteers' bouquet, 1531.
Vouapa spp. (resin), 1623, 1666.
Vraic, potash from, 263–5.
Vulcanized fibre, 618, 1162.
—— guttapercha, 1163.
—— indiarubber lute, 631.
Vulcanizing indiarubber, 1151.
—— oils, 1482.
Vulpes spp. (fur), 1031.

WACHHOLDERBRANNTWEIN, 222–3.
Wachs, 2042–6.
Wagatea spicata (tannin), 1994.
Waggon-grease, 1797–8.
Wahoo, 826.
Walfischspeck, 1374–5.
Walkhoff's mixed method of extracting beet-juice, 1840–1.
Wallace's process (sulphuric anhydride), 98.
Wallflower extract, 1529.
Wall's press (candles), 587.
Walnut (acetic acid), 14, (nut) 1360, (woods), 2022.
—— [country], 1352.
—— -husks (dye), 868.
—— -oil, 1413, 2024.
Walrath (oil), 1371–2.
Walrossöl, 1374.
Walrus-ivory, 1175.
—— -oil, 1374.
—— -skins, 1759.
Waltheria glomerata (drug), 818.
Warang bast, 962.
Warnerke's photo-engraving process, 1619.
Warping cotton, 766, 769.
—— jute, 1184.
Warren's "bromo," &c., caoutchouc wires, 1153.
—— thionoline, 1162.
Washed collodion emulsion, 1538.
Washing charcoal (beet-sugar), 1852–3.
—— esparto, 1487.
—— indiarubber, 1143.
—— powders, 1792.
—— starch, 1824–5, 1829.
—— sugar-beets, 1837.
—— -trough (photography), 1538–9.
Wash-stocks (bleaching), 507.
Wasserharz, 1680.
Waste grease, recovery of, 605–6, 1465–6.
—— paper, 1486.
—— products as source of acetic acid, 26.
—— —— of china clay, 638–9.
—— utilization of tank (soda), 312–3.
Water, 426.
—— aerated, 362.
—— and glycerine, table, 1801.
—— [natural], carbonic acid in, 45.
—— [sea], chloride potassium from, 265–6.
—— —— composition of, 1715.
—— -chestnut, 1359.
—— determination of, in sugar, 1946.
—— for soap-making, 1769.
Water frame (cotton manufacture), 760.
—— glass, 316.
—— -gutters, lute for, 631.
—— in woods, 8.
—— -marks in paper, 1494.
—— solubility of salt in, 1711.
—— varnishes, 2038.
Waterhouse's photo-engraving process, 1620.
Waterlow's copying portfolio, 1609.
Waterproof cement, 628.
—— fabrics, drying, 1148.
—— —— testing, 1153–4.
—— for hats, 1110.
—— glue, 622.
Waterproofing fabrics, 1148.
Waters (perfumes), 1532.
Wattle-bark, 1986–7.
—— gum, 1621, 1632–3.
Watt's process (chromic acid), 48.
Wawla bast, 962.
Wax 586, 2042–6.
—— bees, 2042–4.
—— carnauba, 2044.
—— Chinese white, 2044.
—— Cordillera, 2044.
—— fig-tree, 2044.
—— ibota, 2045.
—— Indian white, 2045.
—— Japan, 2045.
—— koga, 2045.
—— myrica, 2045–6.
—— ocuba, 2046.
—— ozokerit, 2046.
—— palm, 2046.
—— petha, 2046.
Weaving cotton, 766, 780.
—— hair cloth, 1101.
—— jute, 1185.
—— linen, 1254.
—— shed (cotton manufacture), 767.
—— silk, 1756.
Wedgwood's jasper ware, 1598.
Wegwart, 631–3.
Weihrauch, 1676–7.
Weinmannia racemosa (tannin), 1994.
Weinrich's centrifugal, 1935.
Weinsäure, 174–90.
Weinstein, 279, 335.
Weisses sandelholz, 1527–8.
Weizenstärke, 1828–9.
Weld, 868.
—— oil, 1415.
Weldon's process (bleaching-powder), 462.
—— still (bleaching-powder), 466.
Wellman card (cotton manufacture), 746.
Wermuthextract, 217–9.
West African copal, 1642–4.
—— —— elemi, 1649.
—— —— frankincense, 1649–50.
—— —— pepper, 1814.
—— —— rubbers, 1655–6.
—— End bouquet, 1531.
—— Indian guanos, 1258.
—— —— sugar-canes, 1861–2.
—— Indies, tobacco in, 1340.
—— Wetzel's pan (cane-sugar), 1892.
Whalebone, 524.
Whale-oils, 1361, 1369, 1374–5.
Whawhako (tannin), 1993.
Wheat-starch, 1828–9.
Wheatstone's type-writers, 1607.
Whisky, 228.
White arsenic, 336.
—— copalba, 1639.
—— dammar, 1644, 1678.
—— kernel oil, 1408.
—— -lead, 1551.
—— oil, 1410.
—— pepper, 1814.
—— pigments, 1550–1.
—— rose extract, 1529.
—— salt, 1724–40.
—— —— composition of, 1735.
—— Sennar gum, 1631.
—— whale oil, 1369.
Whitewood-tree (oil), 1418.
White's polychrome print, 1604.
Whiting, 1551.
Wichse, 450–2.
Wicken coprolites, 1261.
Wicks (candles), 590.
Wickströmia sp. (drug), 819.
Widdringtonia juniperoides (timber), 2014.
Wieliczka salt-mine, 1723.
Wild cardamom, 1804.
—— nutmeg, 1812.
—— rosemary (narcotic), 1308.
Wilhelm's Quelle water, 365.
Wilkinson's white, 1551.
Willis' aniline photo-engraving process, 1616–7.
Willow (acetic acid), 14, (potash) 255, (charcoal), 882–4, (timber) 2022.
—— (cotton manufacture), 739.
Willughbeia edulis (rubber), 1655 1658, 1664.
Wilson's disintegrator, 1227.
Winding cotton, 766, 768, 777.
—— rope and twine, 1698–9.
—— silk, 1749–50.
Windows, glass mosaic for, 1084.
Windrowing sugar-canes, 1868.
Windward oil, 1407.
Wine, 432–50.
—— alcohol from, 201.
—— bottling, 447–8.
—— classification, 440–1.
—— deterioration, 447.
—— fermentation, 435–7.
—— fortification, 437–8.
—— generalities, 432–5.
—— -glass making, 1070.
—— imitation, 443–7.
—— lees, carbonate potash from, 259.
—— —— tartaric acid from, 183.
—— maturation, 438–40.
—— mixing, 441.
—— preparation of must, 435.
—— preservation, 441.
—— production, 448–50.
—— racking, 438.
—— storage, 438–40.
—— strengthening, 442–3.
—— tartaric acid in, 174.
—— testing, 441.
—— vintage, 435.
Winged cardamom, 1804.
Wintergreen extract, 1529.
—— oil, 1431–2.
Wittedoorn (resin), 1632.
Woad, 868.
Wodjendel (resin), 1676.
Wohlgerüche, 1523–32.
Wolf fur, 1033.
Wolfram, 318.
Wolle, 2046–7.
Wollmanufactur, 2047–2112.
Wolverine fur, 1033.
Wood-apple gum, 1621, 1692–3.
Wood ashes, potash from, 255–7.
—— boiling, 1493–4.
—— cement, 626.
—— cracks, lute for, 631.
—— distillation, products of, 7–21.
—— distilling works, 12.
—— engraving on, 1610–3.
—— for match-splints, 1277, 1279.
—— marten fur, 1031.
—— naphtha, 35.
—— oil, 1411–2, 1640, 1651–2.
—— pulp for acetic acid, 19.
—— —— for paper, 1485.
—— tars, 1683–4.
—— treatment of, for paper-making, 1493–4.
Woodruff (perfume), 1528.
Wood-shock fur, 1030.
Wood-violet bouquet, 1530.
Woodbury machine (brushes), 545.
—— process, 152–3.
—— -type, 1617.
Wooden vessels, lute for, 631.
Woods, 2012–23.
—— for acetic acid, 8.
—— —— gunpowder charcoal, 882–4.
—— products from, 14.
—— water in, 8.
Woody fibre, oxalic acid from, 168–72.
Wool, 2046–7.
—— and cotton, mixing, 2068–9.
—— —— silk waste, mixing, 2068.
Wool beaming, 2078–9.
—— blending, 2067–71.
—— burling, 2082.
—— burring, 2066–7.
—— carbonized, 2058–9.
—— carding, 2071–6.
—— characters, 2051–2.
—— cloth finishing, 2087–8.
—— combing, 2088–90.
—— commerce, 2046–7.
—— condensing, 2071–6.
—— cropping, 2085–6.
—— designing, 2078.
—— drawing, 2090–1.
—— drawing-in and twisting, 2079.
—— drying, 2063–5.
—— fearnought, 2070–1.
—— first raising nap, 2083–5.
—— finishing processes, 2083–8.
—— fulling, 2082–3
—— knotting, 2082.
—— manufactured, 2057–9.
—— manufacturing, 2077–106.
—— milling, 2082–3.
—— oiling, 2069–70.
—— opening, 2065–6.
—— qualities, 2056–7.
—— roving, 2091.
—— scribbling, 2071–6.
—— scouring, 509, 2061–3, 2082.
—— shearing, 2085–6.
—— sizing, 2078.
—— sorting, 2060–1.
—— spinning, 2076–7, 2091–4.
—— stapling, 2060–1.
—— steam-boiling, 2086.
—— structure, 2049–52.
—— twining, 2077–8.
—— twisting, 2077–8.
—— varieties, 2053–6.
—— warping, 2078.
—— washing, 509, 2061–3.
—— weaving, 2079–81, 2091–5.
Woollen-bleaching, 508–15.
—— —— all wool, 513–4.
—— —— cloth scouring, 512.
—— —— —— sulphuring, 513.
—— —— muslin-de-laine, 513–4.
—— —— wool scouring, 509–10.
—— —— —— washing, 509.
—— —— yarn scouring, 511.
—— —— —— sulphuring, 511–2.
—— manufactures, 2047–112.
—— —— bibliography, 2112.
—— —— carpet, 2095–2106.
—— —— commerce, 2111–2.
—— —— finishing processes, 2083–8.
—— —— generalities, 2047–9.
—— —— history, 2047–8.
—— —— processes of manufacture, 2059–2106.
—— —— products, 2106–9.
—— —— statistics, 2109–11.
—— —— worsted, 2088–95.
—— yarn scouring-machine, 511.
Woorari, 810.
Worcester carpet, 1101.
—— ware, 1596–7–9.
Working results (sulphuric acid), 78, 90.
Wormseed, 826, (oil) 1432.
Wormwood-oil, 1432.
—— potash from 255.
Worrall's singeing-machine (bleaching), 473.
Worsted, 2088–95.
Wourali, 810.
Woven silk, scouring and bleaching, 520.
Wrightia antidysenterica (oil), 1415.
—— spp. (resin), 1694.
—— tinctoria (dye), 858.
Writers, manifold, 1608–10.
Writing-inks, 1165–7.
Writing machine, 1606–8.
Wu-pei-tze (galls), 1984.
Würfelsalpeter, 315–6.
Wurmsamen, 826–7.
Wurze, 1802–17.
Wych-houses, 1734.

XANTHIOID cardamom, 1804.
Xanthorrhœa quadrangularis, 1626.
—— resin, 1624, 1693.
—— spp. (resin), 1624, 1693, 2025.

Xanthorrhœa, yellow, 1626.
Xanthorrhiza apiifolia (dye), 856.
Xanthoxylum Clava Herculis (dye), 855–6.
Xerotes spp. (fibre), 999.
Ximenea spp. (oil), 1415.
Xylidine, 660.
—— red, 664.
Xylocarpus Carapa (oil), 1386.
Xylol, 648, 2026.
Xylonite, 610.
Xylopia spp. (fibre), 999.
Xylotrechus quadrupes (coffee), 699.

YACHT Club bouquet, 1531.
Yak-hair, 1099.
Yarn bleaching (cotton), 506–8.
—— sulphuring, 511.
Yarns, 1696, 1762–3.
Yashqui (fibre), 916.
Yeast-plant, 6.
Yegaar (resin), 1676–7.
Yellow alizarine, 684.
—— coralline, 680.
—— crystals, concentration, 1894–5.
—— —— defecation for, 1888–9.
—— lakes, 1551–2.
—— pastilles, 1530.
—— pigments, 1551–2.
—— soaps, 1780–1.
—— spirit (mordant), 1302.
—— water-iris (fibre), 962.
—— wood, 2022.
Yercum (fibre), 933.
Yew tree, 2022.
Young copal, 1643.
Young's splint cutting and filling machines (matches), 1286–8.
Yucca spp. (fibre), 999.
Yungan-oil, 1365.
Yusan (oil), 1377.

ZACHUN oil, 1413.
Zah (resin), 1630.
Zamia spp. (starch), 1823.
Zanzibar copal, 1641–2.
Zea Mays (oil) 1415, (starch) 1823, (sugar) 1908–14.
Zeitlosen, 808.
Zeugdruckerei, 827–54.
Zibeth (perfume), 1524.
Zieger-kraut (perfume), 1528.
Zieria Smithii (oil), 1433.
Zimmt, 1805–7.
Zinaline, 670.
Zinc acetate, 39.
—— amalgam, 334.
—— assay, 357.
Zinc detection, 349.
—— lute, 631.
—— mordants, 1303.
—— white, 1551.
Zincography, 1606.
Zingiber officinale (oil), 1421, (spice) 1809–10.
Zitwersamen, 826–7.
Zizania aquatica (fibre), 999.
Zizyphus flexuosa (resin), 1694.
—— jujuba (resin), 1624.
—— spp. (resin), 1668.
Zuccato's papyrograph, 1608–9.
Zucker, 1830–1977.
Zuckersand, 1903–4.
Zuckersiederei, 1921–35.
Zündholzchen, 1277–93.
Zweifach chromsäures kali, 266–7.
—— kohlensäures kali, 260–1.
—— schwefelsäures kali, 279.

LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.